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ARTES SCIENTIA VERITAS

Published by
Authority of the Lords Commissioners of the Admiralty.

A MANUAL
OF
SCIENTIFIC ENQUIRY;

PREPARED FOR THE USE OF

OFFICERS IN HER MAJESTY'S NAVY;

AND

TRAVELLERS IN GENERAL.

ORIGINALLY EDITED BY

SIR JOHN F. W. HERSCHEL, BART.

Third Edition,

SUPERINTENDED BY THE

REV. ROBERT MAIN, M.A., PRES. R.A.S.

LONDON:
JOHN MURRAY, ALBEMARLE STREET,
PUBLISHER TO THE ADMIRALTY.
1859.

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1859

LONDON: PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
AND CHARING CROSS.

MEMORANDUM

By the Lords Commissioners of the Admiralty,

Relative to the Compilation of a Manual of Scientific Enquiry, for the use of Her Majesty's Navy.

(Prefixed to the First Edition of 1849.)

It is the opinion of the Lords Commissioners of the Admiralty that it would be to the honour and advantage of the Navy, and conduce to the general interests of Science, if new facilities and encouragement were given to the collection of information upon scientific subjects by the officers, and more particularly by the medical officers, of Her Majesty's Navy, when upon foreign service; and their Lordships are desirous that for this purpose a Manual be compiled, giving general instructions for observation and for record in various branches of science. Their Lordships do not consider it necessary that this Manual should be one of very deep and abstruse research. Its directions should not require the use of nice apparatus and instruments: they should be generally plain, so that men merely of good intelligence and fair acquirement may be able to act upon them; yet, in pointing out objects, and methods of observation and record, they might still serve as a guide to officers of high attainment: and it will be for their Lordships to consider whether some pecuniary reward or promotion may not be given to those who succeed in producing eminently useful results.

Their Lordships are aware that in the instructions prepared under the directions of the Royal Society for the Antarctic expedition; in the hints for collecting information given to officers on the expedition to China; in the excellent book by A. Jackson, entitled 'What to Observe;' and in other documents and publications—the fullest directions are to be found; but they are either more voluminous or more closely confined to objects which regard particular localities than is to be desired for a general Manual. Their Lordships are, therefore, desirous that a new compilation should be made, and are satisfied that their wishes would be best met if they could obtain the assistance of some of our most eminent men of science in the composing, by each, of a plain and concise chapter upon the head of inquiry with which he might be most conversant; and they have been readily and kindly promised the advice and labour of Sir John Herschel in revising the whole and preparing it for publication. The several heads of inquiry are as follows:—

Astronomy.
Botany.
Geography and Hydrography.
Geology.
Mineralogy.
Magnetism.
Meteorology.
Statistics.
Tides.
Zoology.

Independently of matters of exact science, their Lordships would look, in many instances, for Reports upon National Character and Customs, Religious Ceremonies, Agriculture and Mechanical Arts, Language, Navigation, Medicine, Tokens of value, and other subjects; but for these only very general instructions can be given, though valuable Reports may be expected from men of observation and intelligence acting under the encouragement which the notice of whatever is well and usefully done is certain of affording.

It would give additional value to each chapter if the name of him by whom it might be composed should be affixed to it; and their Lordships are anxious that no time be lost in the preparation of this work. They are sending a surveying vessel to New Zealand, and have others in the Torres Straits and in other parts of the world. A new establishment is contemplated at Borneo. Expeditions are proposed in search of Sir John Franklin. They have cruisers in every sea; and where the ships of the navy are not present, it sometimes happens that the vessels of the merchant are conducted with much intelligence and enterprise: and for all of these the work proposed would be valuable.

PREFACE TO THE THIRD EDITION.

THE second edition of the Admiralty Scientific Manual, which was published in 1851, being out of print, I was requested to undertake the superintendence of a new edition of the work. In undertaking this, I have been anxious to render the separate articles composing it proper representatives of the respective sciences of which they treat; and my first care, therefore, was to refer them to their original authors for revision, in all cases in which reference to them was practicable, and in all other cases to request the aid of the learned societies devoted to subjects treated of by authors unhappily removed by death since the publication of the second edition.

I have to express my grateful thanks for the readiness with which my requests have been attended to in every instance; and the consequence is, that the book has received a thorough revision by gentlemen best versed in the various subjects treated of, and may therefore be fairly considered to form an excellent guide to scientific inquiries of every class. In particular, the articles, *Terrestrial Magnetism*, *Earthquake Phenomena*, and *Botany*, have been in a great measure re-written for this edition: the first by General Sabine, assisted by Mr. Welsh,* Director of the Kew

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* Since this was written intelligence has been received of the death of Mr. Welsh, after a long and painful illness. Science has sustained a severe loss in the removal of this gentleman at so early an age from labours which have been already eminently useful.

Observatory; the second by Mr. R. Mallet; and the third by Sir William Hooker, assisted by Mr. Hanbury. The subject of *Atmospheric Waves* has also been revised with great care by its author, Mr. Birt. Of the rest it may be mentioned, that a few additions have been made by the editor to the article *Astronomy*, and a few notes are added to this article and to *Meteorology*. The latter article has the advantage of a small addition from its author, Sir J. F. W. Herschel. *Geography*, *Medical Statistics*, and *Zoology* have also received the kind attention of their respective authors, Mr. W. J. Hamilton, Dr. Bryson, and Dr. Owen. The articles *Tides* and *Geology* were referred to their authors, who, however, did not find occasion to make any alterations. The articles of which the original authors have been removed by death are, *Hydrography*, written by Admiral Beechey; *Statistics*, written by Mr. Porter; *Mineralogy*, by Sir Henry de la Beche; and *Ethnology*, by Dr. Prichard. With regard to these, Captain Washington kindly undertook the revision of Hydrography; Statistics was undertaken by Mr. Newmarch, on the part of the Statistical Society; Mineralogy, by Professor W. H. Miller, of Cambridge; and Ethnology by Mr. Wright, on the part of the Ethnological Society.

The only alteration of any importance made in the present edition is in the arrangement of the articles, in which a classification has been attempted, which, it is hoped, will be found advantageous. The subjects are arranged in four divisions, in the following order:—1st. Those which are either purely astronomical, or which require in their developement the principles of spherical or physical astronomy. 2nd. Those which relate to phenomena occurring on the surface of the earth, or in its atmosphere. 3rd. Those which relate to the political and physical geography of the globe. 4th. Those which have reference to the crust of the earth, either directly or indirectly.

In the first division I have placed *Astronomy*, *Hydrography*, and *Tides*. The second division embraces *Terrestrial Magnetism*, *Meteorology*, and *Atmospheric Waves*. The third division includes *Geography*, *Statistics*, *Medical Statistics*, and *Ethnology*. Finally, the fourth division includes *Geology*, *Mineralogy*, *Earthquake Phenomena*, *Zoology*, and *Botany*. It was a question whether the natural sciences, Zoology and Botany, should not form a separate division; but as they are connected with Geology, by means of the fossil remains of plants and animals which are treated of in that science, it was thought more strictly logical to put them in the same division. It must be also remembered that the arrangement here made of the articles is made with a view to order and convenience, and that no very nice accuracy of classification is attempted.

One omission only has been made—namely, that of the Appendix prefixed to Ethnology by the learned editor of the first edition of the Manual, Sir John Herschel. Of this he himself speaks doubtingly in his Preface, as "an intended (though still confessedly incomplete) attempt of his own to facilitate the reduction to writing of foreign native languages, ... a system which, on maturely weighing it, appeared liable to serious objections. The subject is confessedly difficult. . . . ." Both Mr. Wright and M. d'Avezac agree respecting the difficulty of carrying out such a system. Mr. Wright says, "I should say this appendix would be quite as well omitted. There are very few persons who have a nice perception of the sounds of foreign languages, such as French and German, and the table is calculated to lead to much more confusion and misrepresentation on the part of those who use it, than would be the case if they were allowed to represent the sounds of the language of races of low civilization by the known sounds of their own tongue." M. d'Avezac also appends the following note: "Cette partie, très difficile, me parait laisser beaucoup à désirer." Under these circumstances it appeared to me that it was proper to bow to the decision of such eminent authorities, and to omit the table.

The only merit claimed in the superintendence of this edition consists in the arrangements made for securing a satisfactory revision of all the articles, either by their original authors or by the proper representatives of the respective sciences, which required a good deal of correspondence involving an expenditure of time and labour, and in the attention which has been paid to a tolerably accurate classification, as well as to the correct printing of the work; but it is hoped that, through the unsparing labour and zealous co-operation of the authors of the articles and their representatives, the book is rendered a very valuable contribution to science, and that it will be a most important help to all persons who may be, either from opportunity or inclination, capable and desirous of collecting additional facts on the subjects treated of.

Robert Main.

Royal Observatory, Greenwich,
May 9, 1859.

LIST OF ARTICLES.

First Division.

Page
I.—ASTRONOMY .. .. By G. B. Airy, Esq. (Astronomer Royal) 1
II.—HYDROGRAPHY .. .. .. By the late Rear-Admiral F. W. Beechey (Revised by Captain Washington, R.N.) 15
III.—TIDES .. .. By The Rev. Dr. Whewell, Master of Trin. Coll., Camb. 65

Second Division.

I.—TERRESTRIAL MAGNETISM By Major-General Sabine, assisted by Mr. Welsh 86
II.—METEOROLOGY .. .. .. By Sir J. F. W. Herschel, Bart. 120
III.—ATMOSPHERIC WAVES .. By W. R. Birt, Esq., F.R.A.S. 170

Third Division.

I.—GEOGRAPHY .. .. By W. J. Hamilton, Esq., F.R.G.S. 190
II.—STATISTICS .. .. By the late G. R. Porter, Esq. (Revised by W. Newmarch, Esq.) 219
III.—MEDICAL STATISTICS .. .. By Alexander Bryson, Esq., M.D. 236
IV.—ETHNOLOGY .. .. By the late J. C. Prichard, Esq., M.D. (Revised by T. Wright, Esq.) 253

Fourth Division.

		Page
I.—GEOLOGY	By Charles Darwin, Esq., F.R.S., F.G.S.	268
II.—MINERALOGY	By the late Sir Henry De la Beche (Revised by Professor W. H. Miller)	300
III.—EARTHQUAKE PHENOMENA	By Robert Mallet, Esq., C.E.	325
IV.—ZOOLOGY	By Richard Owen, Esq., M.D., LL.D.	364
V.—BOTANY	By Sir William Hooker, K.H., D.C.L.	413

CONTENTS.

(*The figures refer to the pages.*)

First Division, Section 1.

ASTRONOMY.

General Astronomy, 1 — Sextant-observations of comets, 1 — Use of Becher's horizon, 2 and 7 — Eclipses of the sun, 3 — Occultations of stars and eclipses of Jupiter's satellites, 4 — Atmospheric refraction, 4 — Variable stars, 5 — Meteors, 5 — Zodiacal light, 6. Nautical Astronomy, 7 — Observations of occultations of stars and of eclipses of Jupiter's satellites at sea, 7 and 13. Astronomical Geography, 8 — Latitudes and longitudes, 8. Appendix I.: List of conspicuous variable and periodic stars, 10 — List of stars in order of brightness, 11 and 12. Appendix II.: On comet-observations made with the sextant, 12 — On determination of latitude and longitude on shore, 14.

First Division, Section 2.

HYDROGRAPHY.

Making a passage, 15 — Currents, 19 — The stream or surface-drift, 21 — Approaching a coast, 25 — Lighthouses, 29 — Observations in port, 30 — Survey of a port, 31 — Sailing directions, 36 — Tide pole, 36 — Soundings, 37 — The Bore, 39 — Freshes, 40 — Discovery of land, 40 — Sailing along a coast, 41 — Running survey, 42 — Coral islands, 45 — Rivers, 46 — Lakes, 48 — Artificial harbours, 48 — Foreign ports, 49 — Waves, 49 — Form of journal, 51 — Heights and distances of objects, 52 and 53 — Form for register of soundings, 54 — Table of lengths of degrees of longitude, 55 — Forms for tide registers, 56 and 57 — Construction of a chart for a running survey, 58 and 59 — Coasts and islands of which our hydrographic knowledge is imperfect, 59 — Useful abbreviations in surveying, 64.

FIRST DIVISION, SECTION 3.

TIDES.

Directions for tide observations, 65 — Specimen of tide curve, 68 — Establishment of a port, 69 — Lunitidal intervals, 70 — Curve exhibiting lunitidal intervals, 71 — Semi-mensual inequality, 71 — Diurnal inequality, 73 — Double half-day tides, 75 — Progress of the tide, 76 — Mean establishment, 77 — River-tides and bores, 78 — Effect of wind on tides, 79 — References to works on tides, 79 — Rules for finding the hour of high water when the establishment is known, 80 — Rule of the diurnal inequality, 82 — Form for tide-observations, 83 — On the progress of the tide-wave, 83.

SECOND DIVISION, SECTION 1.

TERRESTRIAL MAGNETISM.

Absolute measurement of the magnetic force, 87 — Relative measurements of the magnetic force, 90 — Direction of the earth's magnetic force, 92 — Local attraction, 94 — Summary of the observations to be made, 95 — Record and transmission of the observations, 96 — Application of the results, 96 — Description and use of the Unifilar magnetometer, 99 — Observations of deflection, 100 — Observations of vibration, 102 — Value of horizontal component of earth's magnetic force, 104 — Observations of declination, 105 — Observations of the inclination with Barrow's dip-circle, 108 — Observations of the total force with Barrow's circle, 110 — Directions for using Fox's apparatus for observing the magnetic inclination and force, 112 — Observations of inclination at sea, 113 — Observations of intensity at sea, 114 — Observations on shore, 118.

SECOND DIVISION, SECTION 2.

METEOROLOGY.

Rules for keeping a meteorological register, 121 — Regular hours for meteorological observations, 123 — Term observations, 123 — Barometer, 124 — Attached thermometer, 125 — Choice and transport of barometer, 126 — Barometric observations and reductions, 126 — Correction for capacity, 127 — Correction for capillarity, 128 — Correction for temperature, and index correction, 128 — Example of application of corrections to barometric readings, 130 — Thermometer, 130 — Positions for external thermometer, 131 — Self-registering thermometers, 131 — Hygrometers, 133 — Apjohn's formulæ for elastic force of vapour at the temperature of the dew-point, 134 — Rain-gauge, 135 — Anemometer, 135 — Actinometer, 136 — Description of, 137 — Method of use of, 137 — Instructions for making observations with, 138 — Form for registering observations with, 140 — Reduction of actinometer observations, 142 — Thermometers for terrestrial radiation, 144 — Meteorological registers, 144 — Nomenclature for weather, 147 — Occasional observations, 150 — Squalls, storms, and hurricanes or cyclones, 150 — Winds, 154 — Clouds and fogs, 155 — Temperature of the sea, 155 — Blue colour of the sea, 156 — Observations in port or on shore, 157 — Waterspouts, bull's-eye squalls, whirlwinds, 158 — Showers of dust or ashes, 159 — Thunderstorms, lightning, fireballs, &c., 159 — Atmospheric electricity, 160 — Auroral phenomena, 161 — Halos, parhelia, mock-suns, 162 — Zodiacal light and meteors, 162 — Table of corrections for capillarity of barometer tube, 163 — Table of corrections for temperature to barometric readings, 164–5 — Table of elastic force of aqueous vapour for every degree of temperature, 166 — Table of pressures of wind on a square foot for different heights of the column of water in Lind's wind-gauge, 166 — Table of factors for reduction to 60° Fahr. in observations with the actinometer, 167 — Table for ascertaining altitudes with the barometer, with mode of use, 168–9.

Second Division, Section 3.

ON ATMOSPHERIC WAVES AND BAROMETRIC CURVES.

Introduction: Professor Dove's theory of compensating currents in the temperate zones, 170 — General characteristics of the atmospheric wave, 172 — Instance of the course of an atmospheric wave well observed, 173 — Best stations for observing, 173. Observations: Centre of great barometric disturbance on the north-west of Scotland, 177 — Equatorial depression of the barometer, 177 — Necessity of observations at Cape Horn and the Cape of Good Hope, 179 — Calm state of the atmosphere at St. Helena, 179 — Places at which observations could profitably be made, 180 — The meteorological character of the Indian Ocean well known, 181 — Professor Meldrum's paper on the Meteorology of the Indian Ocean referred to, 181 — Example of a gale experienced by the ship 'Fanny Fisher,' 182 — Directions for avoiding the fury of the Atmospheric Wave, 184 — Diagrams representing Dove's Atmospheric Wave, Redfield and Reid's Rotatory Storms, and Cyclonic Converging Segments, 185 — Places within the Tropics that require most attention, 186 — Extra Observations, 187.

Third Division, Section 1.

GEOGRAPHY.

Rapid increase in the study of Geography of late years, 190 — Defects pointed out, 190 — Precautions to be used by the geographer in observing, 191 — Physical Geography, 193 — Importance of physical geographical observations, 194 — Divisions of this part of the subject, 195 — Form of country, 195 — Mountain ranges, 197 — Valleys, 198 — Rivers, 199 — Diagram illustrating affluent and confluent streams, 200 — Nature of the observations to be made on rivers, 201 — Springs, 202 — Lakes, 203 — Lagoons and marshes, 203 — Line of coast, 204 — Oceans, islands, rocks, shoals, &c., 205 — Tides, storms, tempests, &c., 206 — Other objects and phenomena which are worthy of notice, 207 — POLITICAL GEOGRAPHY, 208 — Divisions of political geography, 208 — Population, 208 — What to observe with relation to population, 210 — Language, 210 — Government, 212 — Buildings, 213 — Agriculture, 214 — Trade and commerce, 215 — Questions to be resolved with regard to trade and commerce, 216 — Past history and antiquities of countries visited, 217 — Coins, manuscripts, and works of art, 217.

THIRD DIVISION, SECTION 2.

STATISTICS.

Population, 219 — Methods of ascertaining the numbers of the population, 219 — Employments of the people, 221 — Result of labour, 223 — Hours of employment, 224 — Expenditure of families, 225 — Education, 226 — State of crime, 227 — Public roads, 229 — Home manufactures, 229 — Foreign commerce, 231 — Imports and exports, 232 — Home trade, 232 — Currency and banking, 233 — Weights and measures, 233 — Joint-Stock Companies, 233 — Public revenue, 234 — Municipal regulations, 234 — Hospital accommodation, 234 — Railroads, steamboats, &c., 234.

THIRD DIVISION, SECTION 3.

MEDICINE AND MEDICAL STATISTICS.

Climate as affecting health, 236 — Principal atmospheric elements, 237 — Importance of hygrometrical observations, 238 — Effects of dry and moist air, 239 — State of the pulse at different elevations, 240 — Conduction of terrestrial miasmata, 240 — Importance of accurate hydrographical observations, 241 — Origin and character of febrile diseases, 241 — Local or personal causes of fevers, 242 — Contagious character of fevers on board of ships to be examined, 243 — Yellow fever, 244 — Its treatment, 245 — Idiopathic fever, 245 — Period of incubation in endemic and contagious diseases, 246 — Exanthematous diseases, 247 — Asiatic cholera, 247 — Plague, 248 — Geographical distribution of diseases, 248 — Treatment of diseases amongst uncivilized tribes, 249 — Narcotic poisons, 249 — Preservation of medical plants and seeds, 249 — Mode of keeping medical journals on board ships of war, 250.

THIRD DIVISION, SECTION 4.

ETHNOLOGY.

Objects of the science of Ethnology, 253 — Physical characters of nations, 254 — Complexion and colour, 254 — Shape of the features, 255 — Colour of the eyes, hair, &c., 255 — Stature and weight, 255 — Shape and relative size of the head, 256 — Form and structure of the body, 257 — Muscular strength, 257 — Characteristics of the state of society, 258 — Practice of agriculture, 260 — Mechanical arts, 260 — Metallurgy, 261 — Arts of war, 261 — Clothing, 261 — Domesticated animals, 262 — Art of navigation, 262 — Notions on Physical Science, 262 — Notions of morality, 263 — Regulations of social life, 263 — Polygamy, 264 — Civil government, 264 — Religious impressions and superstitions, 264 — Language, poetry, and literature, 265 — Importance of obtaining specimens of composition, 265 — Methods of obtaining information concerning languages in which no written compositions exist, 266.

FOURTH DIVISION, SECTION 1.

GEOLOGY.

Advantages possessed by naval officers for the acquirement of facts in geology, 268 — Precautions to be observed by collectors of specimens, 269 — Problems still waiting for solution, 270 — Acquirement of the necessary rudimentary knowledge shown to be easy, 270 — List of useful books, 271 — Tools and apparatus, 271 — Rules for collecting, 272 — Methods for observing, 273 — Organic remains, 275 — Necessity of separation of fossils found in different strata, 276 — Importance of individual fossil remains, 277 — Value of collections of recent shells for comparison with those found in tertiary strata, 277 — Rarity and value of bones of vertebrated animals, 277 — Caverns, 278 — Fossil footsteps, 279 — Coal deposits, 279 — Salt deposits, 281 — Cleavage, 282 — Nature of the sea bottom, 284 — Origin of the sorting of pebbles at different depths beneath the sea, 284 — Observations connected with aqueous catastrophes, 286 — Ice-action, 287 — Erratic boulders, 288 — Deposits of "till," 288 — Distribution of organic beings, 289 — Volcanic phenomena, 290 — Craters of elevation, 291 — Aërial dust, 292 — Elevation of the land, 293 — Subsidence of the land, 295 — Coral reefs, 295 — Rate of growth of coral, 296 — Evidence of slow sinking of the land to be sought for on reefs and atolls, 297 — Value of the description of a thick and widely-extended mass of coral rock, 298 — Concluding instructions, 299.

Fourth Division, Section 2.

MINERALOGY.

Classification of minerals, 300 — List of minerals already classified, 301 — Simple apparatus for distinguishing minerals, 301 — List of works giving accounts of the characters of minerals, and the methods of observing them, 302 — Chief characteristics in the discrimination of minerals, 302 — Cleavages, 302 — Goniometers: Carengeot's, Wollaston's, &c., 303 — Books treating of elementary crystallography, 304 — Prices of collections of models in wood, 304 — Distinctions between true crystals and pseudomorphous minerals, 304 — List of works treating of pseudomorphous minerals, 304 — List of works on chemistry useful in the study of mineralogy, 305 — Use of the blow-pipe or dry method in determining the constituents of minerals, 306 — Method of using the blow-pipe, with lists of auxiliary instruments and re-agents, 307 — Tools necessary for the travelling mineralogist, 310 — Hints useful in searching for minerals, 310 — Crystalline and other bodies to be searched for when crystals have been found in a vein, 312 — Importance of observing and recording the association and succession of minerals in veins, 313 — Cavities of igneous rocks, &c., to be searched for minerals, 315 — Minerals of the zoolite family; where commonly found, 316 — Siliceous deposits, agate, stalactites, &c., 316 — Siliceous and calcareous nodules and clay ironstones, 317 — Crystallized minerals found in the bodies of rocks, 318 — Porphyritic rocks, 319 — Observations to be made in volcanic districts, 319 — Isolated minerals in metamorphic rocks, 319 — Minerals found in moraines, 320 — Gold found in rocks and sand, 320 — Minerals occurring in masses or beds, 321 — Coal not confined to rocks of a particular geological date, 321 — Peculiar features usually characterise beds containing coal, 322 — Fossil plants found in the neighbourhood of coal, 322 — Means of detecting coal-beds by the detritus of brooks and rivers, 323.

Fourth Division, Section 3.

EARTHQUAKE PHENOMENA.

Definition of Seismology, 325 — Explanation of the pulse or wave of force, 325 — Instances of elastic waves, 325, 326 — Velocity of transmission of waves of force in different substances, 326 — Magnitude of the wave, 326 — Definition of an earthquake considered as the transit of waves of elastic compression, 327 — Fundamental conditions of the propagation of seismic waves, 327 — List of works to be referred to, 329 — Usual features, &c., of earthquakes, 329 — Primary and secondary phenomena of earthquakes, 329, 330 — Centre of impulse or origin of earthquakes, 330 — Great earth-wave occurring in earthquakes inland, 330 — Secondary elastic waves, 331 — Forced sea-wave, 332 — Sound-waves through the earth and air accompanying fracture, 332 — Phenomena accompanying earthquakes beneath the sea, 332 — Translation of the great sea-wave, its altitude, and volume, 333 — Means of observing earthquake phenomena, 334 — Districts favourable for seismometrical researches, 334 — Mercurial instrument for observing earthquakes, 335-337 — Description of heavy solid pendulum to be employed for violent shocks, 338 — Objection to instruments of this class, 339 — Observations with a bowl of viscous fluid, 339 — Other instruments, 340 — Considerations which determine the direction and velocity of an earthquake shock, 340 — Arrangement of cylinders for determining the direction and horizontal velocity of the shock, 341-3 — Arrangements for determining by means of a common clock the instant of the shock, 345-7 — Summary of observations to be made, 348 — Calabrian obelisks, 350 — Meizoseismic circle or zone, 351 — Remarks on doubtful phenomena worthy of record, 352 — Observations proper to be made in a city overthrown or affected by an earthquake, 352 — Local conditions to be recorded, 353 — Secondary phenomena to be observed, 353 — Sea-waves produced by falls of rock or landslips, 354 — Effect of earthquakes upon wells, springs, &c., 354 — Permanent elevations and depressions of the land accompanying earthquakes, 355 — Effect on rivers, 355 — Observations on the forced sea-wave, 355 — Observations of waves of sound, 356 — Observations on the great sea-wave, 356 — Use of the sextant in measuring the elevation of the crest of the wave, 357 — Means of determining the length of the wave, 357 — Secondary effects of the great sea-wave, 358 — Specimens to be taken of the fragments moved by the wave, 359 — Collateral conditions to be observed, 360 — Effects on man and the lower animals, 360 — Trustworthy traditions to be sought for, 361 — Coseismal and meizoseismal curves to be laid down, 361 — Effects of earthquakes felt at sea, 362 — List of works, 363.

Fourth Division, Section 4.

ZOOLOGY.

Instructions for collecting and preserving animals, 364 — Algæ, 364 — Sponges, 365 — Corallines, 365 — Corals, 365 — Cautions to be observed in collecting, 366 — Instructions for preserving dried specimens, 367 — Recipes for solutions proper for preserving specimens, 368. Infusorial Animalcules, 369—Reference to works, 369 — Methods of collecting specimens of animalcules, 370—Acalephæ, 37 — Echinoderms, 371 — Entozoa, 372 — Epizoa, 373 — Cirrepedia, 374 — Crustacea, 375 — Varnish for crabs, eggs, &c., 376 — Insecta, 376.

MOLLUSCA, 378 — Cephalopods, Spirula, Nautilus Pompilius, &c., 379 — Importance of drawings, 379 — Pholades, Lithodomi, 380 — Solens, Cardia, Tellinæ, Naticæ, Terebræ, &c., 381. VERTEBRATA, 382 — Hunter's directions for preserving large specimens of fish, 382-3 — Interesting fish of which specimens are required, 383-4 — Directions for preserving fishes, 384. REPTILES, 385. BIRDS, 386— Best mode of preserving birds, 387 — Recipe for arsenical soap, 388 — Directions for the collection of birds, 390. MAMMALS, 391 — Directions for skinning quadrupeds, 393 — Directions for packing and labelling specimens, 395 — Necessary materials for determining species, 396. THE HUMAN RACE, 396 — Queries to be resolved by travellers, 397 — Transport of living animals, 398 — Directions for treatment of animals, 398 — Hints for transporting humming-birds, 399 — Importance of specimens of fossils, fossil-bones, &c., 401 — On the use of the microscope on board ship, 402 — The most useful lenses particularized, 404 — Instruments for minute dissection, 405 — Notes of observation in the anatomical examination of an animal, 407 — General directions to be observed during a voyage, 409.

FOURTH DIVISION, SECTION 5.

BOTANY.

Importance of the transmission home of well-preserved living plants or of dried botanical specimens, &c., 413 — Living plants for cultivation, 413 — Seeds, bulbs, &c., 414 — Cuttings, 414 — Rooted plants, 414 — On preserving plants for the herbarium, 415 — Paper, where procurable, 415 — Directions for drying and preserving, 415 — Museum of vegetable products, 417 — Classes of objects to be collected, 417-9 — All regions of the world offer valuable specimens, 419 — Regions almost unknown to the naturalist, 420 — List of botanical works. 420. BOTANICAL AND PHARMACOLOGICAL INQUIRIES AND DESIDERATA, 421 — Copal, 421 — Grains of Paradise, 421 — Cardamom, Olibanum, Myrrh, 422 — Gum Tragacanth, Storax, 423 — Salep, Sumbul Root, Assafœtida, Sagapenum, Galbanum, 424 — Opopanax, Rhubarb, 425 — Catechu, Grass Oils, Gum Benjamin, Siamese Cardamom, 425 — Cassia Bark, Cassia Buds, Galangal Root, Elemi, 426 — Sarsaparilla, Rhatany Root, Malambo Bark, Balsam of Copaiva, 427 — Lignaloe, Lignum nephriticum, Peruvian Bark, Balsam of Peru, 428 — Balsam of Tolu, 429.

A
MANUAL OF SCIENTIFIC ENQUIRY.

ARTICLE I.

First Division, Section 1.

ASTRONOMY.

By G. B. AIRY, Esq., Astronomer Royal.

The science of Astronomy may occasionally derive benefit from the observations of navigators, in the following respects:—

By contributions to Astronomy in general.
By improvement of the methods of Nautical Astronomy.
By accurate attention to Astronomical Geography.

The remarks which follow will be arranged under these heads.

General Astronomy.

1. The first point which calls for attention is the observation of the places of *comets or other extraordinary bodies*, especially those which can be seen only in low northern or in southern latitudes. In regard to these observations (and indeed to almost all others), one remark cannot be too strongly impressed on the observers—that a bad observation, or an observation which is given without the means of verification, is worse than no observation at all. In order to make the observations good, the following cautions must be observed:—

The index-error of the sextant must be carefully ascertained. If it has not been found a short time before the observations, it must be found as soon as possible after them.

The distance of the comet from three conspicuous stars in different directions must be measured with the sextant. The point of the comet which is observed with the sextant should be precisely described. It is desirable that the navigator should be possessed of some star-maps or star-charts, by means of which he will be able at once to give the proper names to the stars, and much confusion and loss of time will be avoided.

If the time at the ship and the latitude are very well known, there will be no occasion to make further observations; but if these are not well known, some attempt must be made (by the use of Becher's horizon, or by any equivalent method) to ascertain the altitude of the stars and the comet. The lower these objects are, the greater must be the care in the determination of their altitudes.

For affording means of verification, these rules should be followed:—

The observations of distance with the sextant should be entered in the book precisely in the manner in which they are made. The reading of the sextant, *uncorrected*, should be written down: in a column by the side of this should be written the correction for index-error, with a statement whether it is to be added to, or to be subtracted from, the sextant-reading: in the next column should be written a reference to the observations by which the index-error was determined: and in the last column should be written the distance as corrected. For the altitudes, the height of the eye, the depression of the horizon, and the altitude corrected for depression, should also be stated. At some convenient place, either at the beginning or at the end of all, should be written out all the measures by which the index-error was ascertained, exactly in the manner in which they were made, and so that any other person can deduce from them the value of the index-error.

The time of making every observation should be entered exactly as it is read from the chronometer or hack-watch. By the side of this should be placed the error of the chronometer or hack-watch on Greenwich time, or on time at the ship (as may be most convenient); and, after this, the corrected time.

At some convenient place, either at the beginning or the end, must be written out all the observations by which the error of the chronometer is ascertained. If its error on Greenwich time is given, the longitude of the ship must also be given, and the means and observations by which that longitude has been determined must be stated at length.

If a hack-watch is used, the comparison of the hack-watch with the chronometer must be given.

The last observations by which the latitude was determined, and the course and rate of sailing of the ship, must also be given.

All the observations should be sent in this detail to the Admiralty or other body appointed to receive them.

2. Opportunities will sometimes occur, when a ship is lying in a harbour of which the latitude and the longitude are well known, for observing *eclipses of the sun.* These observations are almost always valuable. It can seldom be expected that the time of the beginning of an eclipse can be observed accurately, but the time of the end of it can usually be observed with very great accuracy. And if the eclipse is total, the times of beginning and end of the totality can be observed accurately; if it is annular, the times of beginning and end of the annularity can be observed accurately. The observations should be made with the largest telescope which the navigator possesses; and any peculiarity of distortion of the sun's limb or the moon's limb, any light surrounding the moon, &c., should be carefully recorded. If the eclipse be total, attention should be paid to any coloured or other appendages projecting from the dark edge of the moon, also to the luminous corona surrounding the moon, its apparent breadth, and whether apparently concentric *with the moon* or with the

sun near the moments of beginning and end of the total obscuration.* While the eclipse is in progress, but especially near the beginning or the end, measures of the distance between the cusps or sharp points at which the moon's limb crosses the sun's limb may be repeatedly taken. In recording these observations, the observations by which the time is determined, and the observations by which the index-error of the sextant is determined, should be written down in the fullest detail; and the unreduced observations should be given as well as the reduced observations.

3. In similar circumstances *occultations of stars by the moon* may frequently be observed. *Eclipses of Jupiter's satellites* may also be seen; and (if the navigator have a telescope somewhat better than is usually carried in ships, and steadily mounted) the passage of Jupiter's satellites, either behind the planet or in front of the planet, may be seen, and the times at which the centres of the satellites just touch the edge of the planet may be observed. All these observations will be useful: the observations must be recorded with the same fulness which has been mentioned before.

4. It may chance that the navigator is in some climates where the air is much more damp, and in others where it is much more dry, than in Europe. It is possible that in these places he may be able to make observations which will throw some light upon the influence of moisture in atmospheric refraction. It is recommended that repeated observations of the altitude of the sun's upper and lower limb be taken when the sun is very near the horizon. It

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[* For the details of the phenomena which have been observed in annular and total eclipses the *Memoirs* and *Notices* of the Royal Astronomical Society should be consulted beforehand, especially vol. xxi. of the *Memoirs*, of which the first part is exclusively devoted to accounts of the Total Solar Eclipse of July 28th, 1851. The accounts given by Mr. Airy and Mr. Baily of the phenomena seen by them in the Total Solar Eclipse of July 8th, 1842, will be found in vol. xv. of the *Memoirs*.—R. M.]

will be necessary that the time at the ship and the latitude be very well known. The thermometer must be read, as also some hygrometrical instrument, and the barometer, if there is one on board, during the observations. The observations of every kind must be recorded with the utmost fulness.

5. It is certain that some of the *stars* of the southern hemisphere are *variable* in magnitude; the most remarkable of these is η Argûs. It is desirable that, on favourable nights, the magnitude of this star should be observed and recorded. The best way of doing it will be, not to state that it looks like a star of the 2nd magnitude, or of the 3rd magnitude, &c., but to compare its brightness with that of some of the stars near it. Thus it will be easy to say that it appears pretty exactly as bright as one star, certainly brighter than a second, and certainly not so bright as a third.*

6. Much attention has been excited by the appearance, in several years, of *meteors* in great numbers, on or about the 9th of August and the 12th of November.† It is probable that these appearances may be seen by persons at sea, when, either from the hour at which they occur, or from other causes not yet understood, they cannot be seen in Europe. It is impossible to observe them with accuracy; but very valuable information will be given by counting repeatedly how many can be seen in some fixed interval of time, as five minutes; and by remarking whether they all come from, or go to, one part of the heavens; what is that part of the heavens; whether they usually leave trains behind them; what is their usual brightness (as compared

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* See a list of variable stars, and some suggestions for observations of brightness of stars, in the Appendix.—(Ed. Sir J. H.)

† Humboldt (Kosmos, i. 337) enumerates the following epochs as especially fertile in meteors, viz. April 22—25; July 17—26; Aug. 9—11; Nov. 12—14 and 27—29; Dec. 6—12. Of all these epochs, that of August has hitherto proved to be the most regular. The star B Camelopardali has for several years been their point of divergence about that epoch. Any change in this respect should be recorded.—(Ed. Sir J. H.)

with that of known stars); and by any other remarks which may be suggested by their appearance.

7. Many opportunities will occur of observing the *zodiacal light;* more especially when the observer is near the equator, where probably it can be seen at all seasons, before sunrise and after sunset; or, if in northern latitudes, after sunset in February and March, and before sunrise in September and October; if in southern latitudes, before sunrise in March and April, and after sunset in August and September. The zodiacal light consists of a pyramid of faint light, whose base is somewhere near the place of the sun, and whose point is at a distance of perhaps 30° from the sun; the axis of the pyramid being usually inclined to the horizon, following nearly the direction of the ecliptic. Although it presents to the eye a considerable body of light, yet the light of any portion of it is so feeble, and the definition of its outline is so imperfect, that it cannot be observed with a telescope. The observer, therefore, should only attempt to observe it with the naked eye when the sky is very clear, and when the sun is so far below the horizon that no twilight is visible. He should then endeavour, with the assistance of a chart of the stars, to define as accurately as possible its boundary with reference to the stars; remarking especially the place of the point of the pyramid, the width where it rises from the horizon, whether its sides are curved, and in what parts the light is brightest. It will be found that these observations are made most accurately by occasionally turning the eye a little obliquely from the zodiacal light. In registering the observation, in addition to the particulars to be recorded as prescribed above, there should be a statement of the latitude of the ship, the day, the time at the ship (or the Greenwich time and the longitude of the ship), the state of clearness of the sky, and the state of the weather for the day preceding the observation.[*] (See also *Meteorology.*)

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[*] A valuable paper by Professor C. P. Smyth on the Zodiacal Light, containing observations made by him near the Cape of Good Hope in the years 1843-5, will be found in the *Transactions of the Royal*

Improvement of Nautical Astronomy.

8. So much attention has been given to every detail of Nautical Astronomy, that it is very difficult to fix upon any part of it to which the attention of navigators should be specially directed with a view to its improvement. Perhaps the principal deficiency at the present time is in the want of well-understood methods of observing (with the sextant) the altitudes of stars at night, and of observing the altitudes of the sun and moon when the horizon is ill-defined. Every endeavour ought to be made to become familiar with the use of Becher's horizon, or some equivalent instrument, and to acquire a correct estimate of the degree of confidence which can be placed in the use of it.

9. It is likewise desirable that efforts should be made to facilitate the observation of *Occultations of stars by the moon*, and the observation of *Eclipses of Jupiter's satellites at sea*. Occultations occur rarely, but the result which they give for longitude is usually so much more accurate than that given by lunar distances, that, in long voyages where little dependence can be placed on the chronometer, the observation of an occultation must be extremely valuable. The eclipses of Jupiter's satellites afford less accurate determinations of longitude, but they occur very much more frequently, and may be very useful where chronometers cannot be trusted.*

Society of Edinburgh, vol. xx. The principal merit of this memoir consists in the actual observations of the vertex of the cone of light by means of a rough instrument made for the purpose. A far more elaborate series of observations of the general boundaries of the light is that made by the Rev. George Jones, between the years 1853 and 1855, while engaged with the United States Japan Expedition in the steam frigate Mississippi. The results of the observations are given in a series of Charts drawn on Mercator's Projection, and form the 3rd volume of the 'Results of the United States Japan Expedition.'—[R. M.]

* Attempts may laudably be made to devise some available mode of suspending a chair, so as to afford a steady seat to the observer. Hitherto such attempts have failed of practical success, from setting out with the principle of perfectly free suspension, a principle which

Astronomical Geography.

10. The intelligent navigator, on arriving at any port which has not before been visited, or whose position is not very well settled, ought to consider it his first duty to determine with all the accuracy in his power the *latitude and longitude* of the port. Supposing him to have determined by the usual nautical methods the approximate latitude, longitude, and error of chronometer, the best method of determining the latitude will be to find the chronometer-time at which the sun or any bright stars of the Nautical Almanac list will pass the meridian, and to observe the double altitude of any such object by reflexion in a mercurial horizon, several times, as near as possible to the time of the meridian passage. If the place is in the northern hemisphere, the observation of the double altitude of the pole-star may be made at any time when it is visible: convenient tables for the reduction are given in the Nautical Almanac. For these and other observations the navigator ought to be provided with a proper trough and a store of mercury. For determining the longitude, there is probably no method superior to that of lunar distances (the exactness of which will be increased if the sextant or reflecting circle be mounted on a stand), unless the stay at the port is so long that transits of the moon can be observed. In any case, if there be a transit-instrument in the ship, it ought to be mounted on shore as soon as possible. The instrument ought, on the first evening, to be got very nearly into a meridional position, and then a mark should be set up, and the instrument should always be adjusted to that same mark (even though it be not exactly in the meridian), and

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tends to prolong and perpetuate oscillations once impressed. It remains to be seen what *stiff* suspension, as for example by a rigid rope or cable, or by a hook's joint, purposely made to work stiffly (and that more or less at pleasure), by tightening collars—as also deadening and shortening oscillations, by lateral cords passing through *rings* to create friction—and other similar contrivances may do. In the suspension of a cot, at least, I have found this principle signally available.—(Ed. Sir J. H.)

should always be levelled, before commencing a series of observations. One or two stars at least, as near the pole as possible, should be observed every night, in addition to the Nautical Almanac stars necessary for chronometer-error, and the moon-culminating stars which are observed with the moon. The instrument should be reversed on alternate nights; and, if possible, as many transits of the moon should be taken after the full moon as before the full moon.

In the register of all these observations, the same rule should be followed which is laid down under the first suggestion; that every observation should be recorded *unreduced*, exactly in the state in which it is read from the sextant or chronometer; and that the unreduced observations should be accompanied with the elements of reduction of whatever kind; and that (if the navigator has had leisure to reduce them) the reduced results should also be given.

G. B. Airy.

APPENDIX No. 1.

By Sir J. F. W. HERSCHEL.

(A.)

A List of the most conspicuous Variable or Periodic Stars of which observations would bo desirable, with their periods of Variation (so far as known) and changes of magnitude.*

Star.	Period.			Change of Magnitude.		
	D.	H.	M.			
β Persei	2	20	48	2	to	4
λ Tauri	4	..	..	3·4	to	4
δ Cephei	5	8	37	3·4	to	5
β Lyræ	6	9	..	3	to	4·5
η Aquilæ	7	4	15	3·4	to	4·5
ζ Geminorum	10	3	35	4·3	to	4·5
α Herculis	60	6	..	3	to	4
ε Aurigæ	19 months		..		..	
ο Ceti	334 days		..	2	to	..
ν Hydræ	494 „		..	4	to	10
κ Sagittarii	Many years		..	3	to	6
η Argûs	Irregular		..	1	to	4
β Ursæ Minoris	Unknown		..	2	to	2·3
α & η Ursæ Majoris	Ditto	..	..	1·2	to	2

(B.)

List of Fixed Stars in either hemisphere, approximately arranged in order of brightness, down to the fourth magnitude, for the purpose of mutual comparison under favourable circumstances of altitude, and especially in equatorial and tropical voyages, or land stations, with a view to bringing the nomenclature and scale of magnitudes in the two hemispheres to agreement, and to the improvement of this branch of astronomical knowledge. The comparisons to be made by the naked eye among the stars of both lists not differing much (at the time of observation) in altitude, and in the absence of the moon and twilight,

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* Much has been done by astronomers since the year 1851 in the observation of known periodic stars and the detection of new ones; for which see the *Notices of the Royal Astronomical Society*.—[R. M.]

and the results arranged in sequences, beginning with the brightest, and ending with the faintest star compared. In each sequence *stars of the two lists should alternate whenever circumstances will allow.*

a. NORTHERN STARS.

Arcturus.
Capella.
α Lyræ.
Procyon.
α Orionis.
Aldebaran.
α Aquilæ.
Pollux.
Regulus.
α Cygni.
Castor.
ε Ursæ Maj.
α Ursæ Maj.
α Persei.
β Tauri.
γ Orionis.
Polaris.
γ Leonis.
ζ Ursæ Maj.
α Arietis.
β Andromedæ.
β Aurigæ.
γ Andromedæ.
γ Cassiopeiæ.
α Andromedæ.
α Cassiopeiæ.
γ Geminorum.
β Leonis.
γ Draconis.
α Ophiuchi.
β Cassiopeiæ.
γ Cygni.
α Pegasi.
β Pegasi.
ε Pegasi.
α Coronæ.

γ Ursæ Maj.
β Ursæ Maj.
ε Bootis.
ε Cygni.
α Cephei.
α Serpentis.
δ Leonis.
η Bootis.
γ Aquilæ.
δ Cassiopeiæ.
η Draconis.
β Draconis.
β Arietis.
γ Pegasi.
ε Virginis?
θ Aurigæ.
β Herculis.
Cor Caroli.
β Ophiuchi.
δ Cygni.
ε Persei.
η Tauri.
ζ Persei.
ζ Herculis.
κ Aurigæ.
γ Ursæ Min.
η Pegasi.
ζ Aquilæ.
β Cygni.
γ Persei.
β Trianguli.
δ Persei.
ε Aurigæ.
α Lyncis.
ζ Draconis.
π Herculis.

β Canis Min.?
ζ Tauri.
δ Draconis.
μ Geminorum.
γ Bootis.
ε Geminorum.
δ Herculis.
δ Geminorum.
π¹ Orionis.
β Cephei.
θ Ursæ Maj.
ι Ursæ Maj.
η Aurigæ.
γ Lyræ.
η Geminorum.
γ Cephei.
κ Ursæ Maj.
ε Cassiopeiæ.
θ Aquilæ.
δ Andromedæ.
η Herculis.
ζ Pegasi.
ε Tauri.
ζ Cygni.
α Trianguli.
ζ Aurigæ.
λ Aquilæ.
μ Herculis.
ι Draconis.
μ Pegasi.
χ Draconis.
η Cassiopeiæ.
θ Pegasi.
ζ Cassiopeiæ.
δ Aquilæ.
μ Herculis.

ξ Geminorum.
κ Geminorum.
ζ Cephei.
η Cephei.
ο Ursæ Maj.?
λ Geminorum.
θ Geminorum.
ο Andromedæ.
β Delphini.
ζ Geminorum.
α Delphini.
41 Arietis.
ι Geminorum.
λ Tauri.
ο Tauri.
ξ Tauri.
η Piscium.
ι Herculis.
δ Bootis.
γ Trianguli.
α Draconis.
γ Tauri.
γ Arietis.
τ Cygni.
ι Cephei.
ξ Herculis.
ο Herculis.
ρ Cygni.
ι Pegasi.
ξ Pegasi.
δ Aurigæ.
γ Sagittæ.
γ Ophiuchi.
φ Draconis.
γ Delphini.
α Piscium.

b. SOUTHERN STARS.

Sirius.
Canopus.
α Centauri.
Rigel.
α Eridani.

β Centauri.
α Crucis.
Antares.
Spica.
Fomalhaut.

β Crucis.
α Gruis.
γ Crucis.
ε Orionis.
ε Canis Maj.

λ Scorpii.
ζ Orionis.
β Argus.
γ Argus.
ε Argus.

α Trianguli Aust.
ε Sagittarii.
θ Scorpii.
α Hydræ.
δ Canis Maj.
α Pavonis.
β Gruis.
σ Sagittarii.
δ Argus.
β Ceti.
λ Argus.
θ Centauri.
β Canis Maj.
κ Orionis.
δ Orionis.
γ Centauri.
ε Scorpii.
ζ Argus.
α Phœnicis.
ι Argus.
α Lupi.
ε Centauri.
η Canis Maj.
β Aquarii.
δ Scorpii.
η Ophiuchi.
γ Corvi.
η Centauri.
κ Argus.
β Corvi.
β Scorpii.
ζ Centauri.
ζ Ophiuchi.
α Aquarii.
π Argus.
δ Centauri.
α Leporis.
δ Ophiuchi.
ζ Sagittarii.
π Ophiuchi.
β Libræ.
γ Virginis.
μ Argus.
δ Sagittarii.
α Libræ.
λ Sagittarii.
β Lupi.
α Columbæ.
ι Centauri.
δ Capricorni.
δ Corvi.
β Eridani.
θ Argus.
β Hydri.
ε Corvi.
β Aræ.
α Toucani.
β Capricorni.
ε Argus.
π Scorpii.
β Leporis.
γ Lupi.
υ Scorpii.
ι Orionis.
α Aræ.
π Sagittarii.
α Muscæ.
α Hydri?
τ Scorpii.
ζ Hydræ.
γ Hydræ.
β Trianguli Aust.
σ Scorpii.
τ Argus.
γ Triang. Aust.
η Serpentis.
ι Scorpii.
υ Argus.
λ Crucis.
γ Sagittarii.
ν Hydræ.
κ Centauri.
N Velorum.
β Columbæ.
ζ Canis Maj.
γ Gruis.
α Indi.
β Muscæ.
λ Centauri.
γ Tubi.
γ Hydri.
ω Argus.
ε Hydræ.
θ Eridani.
ν Argus.
ξ Argus.
ο² Canis Maj.
π Hydræ.
β Tubi.
α Pictoris.
φ Sagittarii.
α Circini.
σ Argûs.
α Doradûs.
β Phœnicis.
δ Aquarii.
ζ Scorpii.

APPENDIX No. 2.

BY R. M.

1. *On Comet Observations made with the Sextant.*

As a proof that such observations are occasionally of very great service the great comet of 1843 may be referred to. This comet, from its low southern position, could not be observed in Europe, and generally there was a great want of observations made with instruments in fixed observatories. But it was an object of great attention to the officers of ships on their passage from southern latitudes towards England, and to many persons in the colonies who were provided with sextants, and several extensive series of observations were sent to the Royal Astronomical Society, and accurately reduced at the expense of that body. The paper containing the results of the calculations is printed in the sixteenth volume of the *Memoirs* of the Society; and the processes and formulæ to be used in such calculations are given in detail. The want of care of some of the observers in giving the requisite elements of reduction was exhibited in a very instructive way, and may be useful to future observers, at the same time that it shows the imperative necessity of attending to the instructions given by the Astronomer Royal at pages 2 and 3 of the Manual. By the greater number of the observers neither the barometer nor the thermometer had been read at all, and it became necessary to supply the defect empirically, in the computation of refraction, by the average pressures and temperatures of the air as deduced from the general results of climatology. Then, again, the computers were frequently ignorant whether the time set down was chronometer time, or mean solar time at place, or Greenwich mean solar time; and, with regard to the measures themselves, no pains were generally taken to give information whether the index-correction had been applied, or, if applied, how it had been obtained. The remarks above are extracted almost verbatim from the paper before referred to, and they need no farther comment.

For the advantage of such officers as have not access to the 'Memoirs of the Royal Astronomical Society,' the formula there used, and found very convenient, for the correction of the observed distances for the effects of refraction and parallax, is here subjoined:—

Let d be an apparent measured distance of the comet from a star.

Z and z the apparent zenith distances of the comet and star (these would generally have to be computed, but at stations on shore they might be conveniently observed with the sextant).

Π The comet's horizontal parallax.

And suppose generally the refraction in altitude to be α tan. z (α being nearly equal to 57").

Then the correction to the observed distance is

$$\frac{1}{\sin d}\left\{\alpha - \Pi \cos Z\right\} \times \left\{\frac{\cos z}{\cos Z} - \cos d\right\} + \frac{\alpha}{\sin d}\left\{\frac{\cos Z'}{\cos z} - \cos d\right\}$$

which is very easily computed.

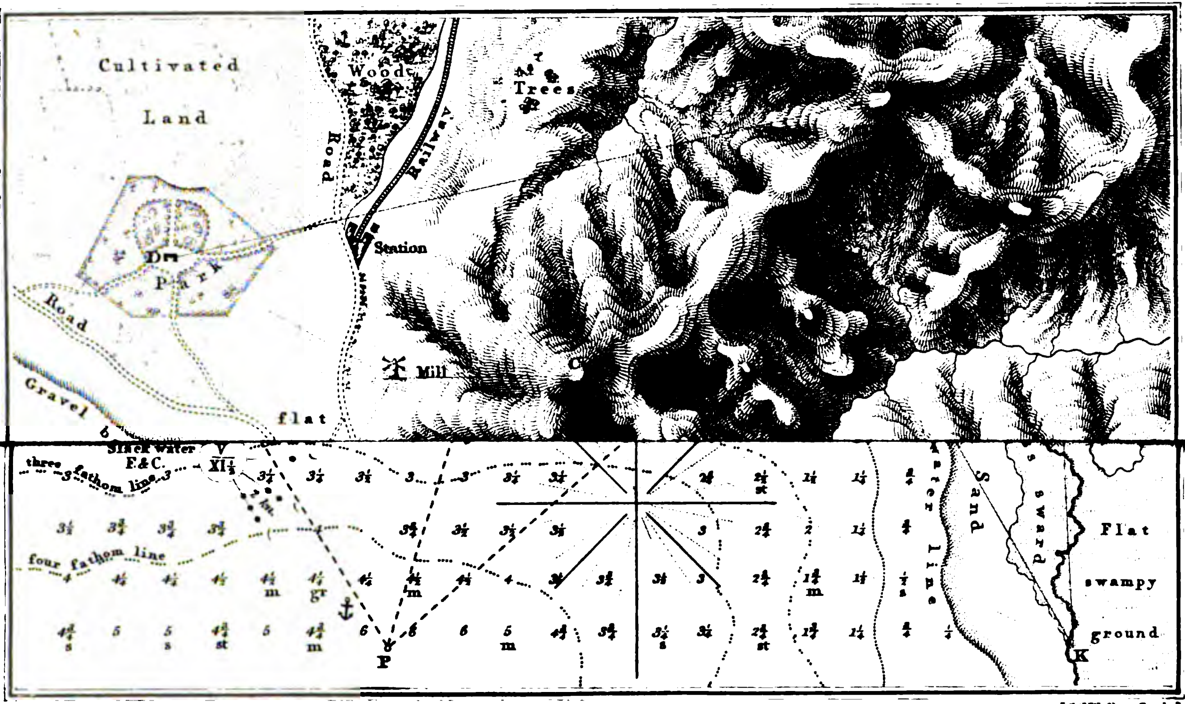
2. *On Observations at Sea of Occultations of Stars by the Moon, and of Eclipses of Jupiter's Satellites.*

Every naval officer is familiar with the attempts which have been frequently made to facilitate the observations of Jupiter's Satellites by apparatus calculated to afford a steady position for the observer, or for the telescope used in the observations. Professor C. P. Smyth seems to have practically solved the problem by means of an apparatus which he designates a Free Revolver Stand, of which a detailed description is given in vol. xvii. of the 'Notices of the Astronomical Society,' page 36. By manual power applied to this apparatus during his passage to Teneriffe in the yacht *Titania*, in 1856, he succeeded in obtaining a perfect level and quiet stand for his telescope, and not only saw himself, but enabled the officers of the yacht to see, the satellites of Jupiter as well as they can be seen on land. (See his 'Teneriffe; or, an Astronomer's Experiment.') It is probable that steam-power would in general be required for the working of the apparatus.

3. *On the Determination of Latitude and Longitude on Shore.*

Every surveying vessel, and every other vessel that is likely to visit stations where the latitudes and longitudes are not at all or not well determined, should be provided with a portable transit-instrument. If the ship should stay even a week at such a station, there would be ample time for the use of the transit-instrument, both in determining local time with great accuracy, and in determining longitude by transits of the moon and moon-culminating stars; and also, by placing it in the prime-vertical, in determining the latitude with far greater accuracy than is attainable with the sextant. For the use of the transit-instrument generally, see 'Loomis's Astronomy,' an excellent American work, which should be in the hands of every scientific naval officer.

Plate A. To illustrate Hydrographic delineation.



J. & C. Walker Sculpt.

Published by John Murray, Albemarle Street, Piccadilly 1859.

ARTICLE II.

First Division, Section 2.

HYDROGRAPHY.

By the late Rear-Admiral F. W. BEECHEY, R.N.

(Revised by Captain Washington, R.N.)

Making a Passage.

The observer's attention is directed first to those objects which affect the passage of a vessel from one part of the globe to another; such as the movement, the duration, the limits, and the periodic occurrences of those great currents of the atmosphere and of the ocean, upon which the speedy and successful issue of a passage mainly depends.

Well recorded and established facts bearing upon the several points connected with these inquiries are highly important to navigation, and may be collected by every assiduous seaman in the ordinary course of his duties.

1. It is well known that in various parts of the globe there exist monsoons, and zones of trade and variable winds: and that these and other disturbances of the atmosphere which influence the surface of the ocean are the principal causes of the many currents which sweep over the face of the earth. The effect of these upon a vessel passing to and fro is one of the most useful inquiries a seaman can make; and as both (wind and current) perform an important part in the economy of nature, an additional interest attaches to a correct knowledge of them. The seaman should therefore not only carefully note the direction and force of the winds, but should connect with such entries notices as to when and where any continued or periodic

wind commenced and terminated; what was its strength and effect upon the passage; whether it came on suddenly, and was furious while it lasted, or otherwise; whether it was preceded by any particular symptoms, and whether it was such as usually occurs at that season; and lastly, whether it be advisable to cross this wind in any particular direction, such as close hauled or large, &c.

2. To detect the current, a more than ordinary attention must be paid to the reckoning of the ship: the compass by which the course is steered should frequently be compared with that by which the variation is determined, in every position of the ship's head;* and the ship's place should be determined by observation at least once a day. Sights for chronometer morning and evening should both be referred to noon, at which time the latitude will of course be observed; and all observations for latitude at night, or for fixing the ship's place at any time, should be referred to one period of the day, in order that the position of the ship *by observation*, as compared with her place by the *Dead Reckoning*, may give the direction and force of the current, if any, for the twenty-four hours. These observations should all be entered in a table; and at the close of certain obvious and natural periods of a passage, such as that of entering or emerging from the trade-wind, the calm latitudes, the commencement or termination of the monsoon, of any positive change of current, or from any continued state of things to another, the whole effect of the current for the period should be deduced, and an average of its daily rate and set be given, together with any remarks which may be considered useful.

3. With the direction of the current thus determined, it is very desirable to connect the temperature of the surface of the sea, for it has been by such observations that we have been able to trace, with a certainty amounting almost to proof, the continuous course of the same body of water for thousands of miles over the troubled surface of the

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* See Article IV., 'Terrestrial Magnetism.'

ocean, and that other curious and important facts in physical hydrography have been ascertained. We would therefore urge attention to the subject as one of considerable importance to navigation. As a proof of its influence upon a passage, we need only instance the remarkable phenomenon of the Equatorial and Guinea currents: two streams in contact, but flowing in opposite directions, and having a temperature differing 10 or 12 degrees from each other, and yet pursuing their opposite courses for upwards of a thousand miles; and according as a vessel is placed in one or the other of these currents, will her progress be aided or retarded from 40 to 50 miles a day.*

Could we but obtain a register of the temperature of the surface of the sea from every ship in active service, we should be able in a short time to construct tables showing the normal temperature of the surface of the ocean for every 5° of latitude for every month in the year, and a comparison of these with the actual temperature of the surface at any particular spot, and in any particular month, would at once manifest an abnormal difference, if any existed, and lead to a knowledge of its cause, which might prove of considerable use to the mariner by acquainting him with the movement of the great body of water in which he was sailing; either retarding or accelerating his progress, as the case might be, and at all events affecting his reckoning. Or it might lead to a closer determination of the limits and periodical changes of currents which, as before observed, are everywhere running over the surface of the sea as rivers run over dry land.†

It is therefore recommended to add to the table of currents a column for the temperature of the open air, and another for that of the surface of the sea, which should be registered frequently during the twenty-four hours; but as such observations form an essential feature in the meteorological register of a voyage, they should be made at the times and in the manner indicated under the head of Meteorology.*

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* Sabine's 'Hydrographical Notices.'

† Such registration is now in progress, and the resulting facts are collected at the Meteorological Department of the Board of Trade. (W.)

4. There should also be noted in the Remark column the occurrence of masses of seaweed, or of any continued appearance even of small patches of this or of any other floating substances which may be seen; and if opportunity offers, deep-sea soundings should be tried at the spot. "It were much to be wished," says Humboldt, *Personal Narrative*, vol. ii. p. 11, "that navigators heaved the lead more frequently in these latitudes covered with weeds, for it is asserted that Dutch pilots have found a series of shoals extending from the banks of Newfoundland to the coast of Scotland by using lines composed of silk thread."† Flocks of birds should also be noted. In many places, the Pacific especially, the tern are useful monitors of an approach to those low specks of coral which endanger the path of the navigator through the labyrinth of the great South Sea. In short, everything that may seem to the voyager to be interesting or new, or likely to be useful, should find a place in the Remark column.

At the end of the passage a summary of these remarks should be given, the whole effect of the current for each particular portion of the passage recapitulated, such as that which was due to the N.E. or S.E. trade-wind, or to the monsoon, as the case might be, and distinguishing each;

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* If passing Cape Horn, or through seas where icebergs may be moving about, these observations cannot be made too frequently in thick weather, especially as a precaution, for the water appears to be influenced to a considerable distance around these masses, particularly in their wake.

A printed registry, termed a Weather Book, with full instructions for observing, is now supplied to all H. M. ships, and to many merchant vessels. This register is called by the American navigators an "Abstract Log."

† In a continuous line of soundings across the Atlantic, between Ireland and Newfoundland, in June 1857, preparatory to laying the telegraph cable, Commander Dayman found a depth of 2400 fathoms, and not the slightest indication of any shoal. But farther northward there may be shallower water. (W.)

that which occurred in the calm latitudes or during a period of variable winds, or otherwise, averaging the daily rate; and then might follow any remarks you may wish to make either upon them or upon any other feature of the passage; together with any directions or hints which might be considered useful to those who should follow over the same ground; such as whether any advantage would have been gained by steering more to the east or west, or in any other direction; whether any time would have been saved by making the land on any other bearing than that in which you hit upon it; and in short any remarks which would be instrumental in conveying to others information which you would have wished to possess yourself at the outset of the passage.

Currents.

5. It is very desirable that observations upon the course of the waters of the ocean should be made without intermission; and that *a continued register* of the temperature of the surface, and occasionally of its submerged strata,* should be kept, as it is only by numerous well-recorded observations of this nature that we shall ever be able satisfactorily to define the limits of the various zones of moving water which sweep over the face of the globe, mingling the waters of the Polar Seas with those of the equatorial regions, and even affecting the climate of extensive districts.† But if from various causes a connected series cannot be continued throughout these great currents, at least an endeavour should be made to commence a register on approaching the limits of such as are now approximately defined, and to continue it while any interest appears to attach to the subject: such as that of the Gulf-stream; the Trade-wind drift; the Guinea and Equatorial current; the

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* By means of self-registering thermometers, properly set and carefully lowered and as carefully hauled in (without jerks).

† See Humboldt on the Climate of Peru; Sabine on the Climate of St. Thomas Island, &c.; Maury on the Physical Geography of the Sea.

Cape of Good Hope current, blending with the south-east trade drift; and the Brazil current, in the Atlantic; with the Mozambique and Agulhas current; the Trade drift, and monsoon current of the Arabian and Bengal gulfs, in the Indian Ocean. Also the remarkable Peruvian current sweeping along the western coast of South America; the Trade drift, and Equatorial current; the Mexican current, passing along from Panamá to the Gulf of California, according to the monsoon; the counter-currents north and south of these, and the moving belt along the coast of Japan and Korea to Kamtchatka, in the great Pacific Ocean. And particularly noting, as of great importance to navigation, the limits of the outer currents around the Cape of Good Hope and Cape Horn, all of which will be found on a small scale delineated in a general chart at the end of this paper. (Plate B.)

Some of these currents maintain a constant difference of several degrees between their own temperature and that of the mean state of the water about them, and all observations which can throw light upon this subject, and upon the limits, course, and velocity of the stream, will be most acceptable.

6. In passing through any of these great currents, the observer should carefully define the extent of the belt of moving water at the parallel in which he crossed it; the limit of the eddy on either side of it; determine the rate and set of both; carefully note every barometrical or thermometrical change of the air, or alteration in the temperature or specific gravity of the sea, and if possible the depths to which these temperatures extend; and record all appearances and changes which may appear of interest or seem to be useful to those who may follow over the same ground.

To detect the motion of the stream the remarks in (2) should be attended to, with the exception that here the position of the ship should be *frequently* ascertained during the day by astronomical observation, and the course and rate of the current deduced for *short intervals* of time instead of for the twenty-four hours. The observations should commence previous to entering the body of moving water, and be continued until after the vessel has quitted it, when it will be advisable to occupy a page of the journal with a graphic delineation of the several courses of the stream, indicated by arrows, and of the several stages of the vessel's progress by the *various* temperatures which have been observed, noting the places where ripples were seen, or where drift-wood, seaweed, or other floating substances occurred.

The Stream or Surface Drift.

7. Currents have been spoken of under the head of "making a passage," as they affect a ship's route across the ocean, and may have been determined by the position of the ship by Dead reckoning differing from that by observation. But it will be proper further to *try the set of the surface* of the water on all favourable occasions, by the ordinary method of anchoring, or of sinking a weight, endeavouring if possible to get observations on the same day at about six hours apart, in order that it may be seen whether the stream be due to a tide or not. If the ship be in soundings, and the day be calm, a very simple way of effecting this without the trouble of either anchoring or lowering a boat,* is to drop a heavy lead from the quarter, and, after it has reached the bottom, to run out a small quantity of stray line, and then make fast the "nipper," or a billet of wood, to the line; and at the same time to fasten the end of the log line to it, and veer away both together.† Then mark by a watch the time *each knot* is in running out, buoying up the line by a chip of wood; when all the line has run out, take the bearing of the nipper by a compass, and haul all in together. If currents be tried

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* An objection to trying the current in a boat is the uncertainty of the compass, unless Dent's spirit-compass be used, which is strongly recommended.

† If the lead-line be not hitched to the nipper, the tide may drag the line through it, and there will be no result.

when there are no soundings, the result is merely the relative motions of the upper and lower strata of the water, and it would be difficult to say which way either were going; but if we can possibly determine by astronomical observations the course of the *upper* surface, we shall thence be able to deduce the set of the *lower*; and if there be found any difference of moment, it will be very desirable to ascertain the temperature of both upper and lower strata of the water, and to record them with the other observations. These observations ought always to be made on calm days, and the greater the depth to which the weight be sunk the better. Bottles thrown overboard with a label inside, containing the date and latitude and longitude of the spot where cast into the sea, afford ready means of detecting the current if picked up afterwards, and ships would do well frequently to expend a few empty bottles in this way.* In the event of meeting any such drifting at sea, they should be picked up, their contents copied, and the date and position of the spot added to the label; they should then be carefully resealed and returned to the ocean, and a copy of the label forwarded to the Admiralty.

8. If near to any shore, a few points of which are well fixed, and the water be found too deep for anchorage, the course of the stream may still be ascertained by noting the drift of a float—a plank, for instance, weighted at one end, so that the other just floats above the surface; or a weighted breaker (*bareca*)—fixing its position from time to time by angles taken in a boat at the several places, and noting the intervals by a watch.

Such methods may, of course, be resorted to when circumstances do not admit of greater accuracy; but whenever it can be done, the course and rate of the stream should be observed *every hour* during *both* tides, and the times of slack water carefully noted, by anchoring a boat or vessel. Upon an open coast one set of such observations, made here and there, well clear of the headlands, will be sufficient; but in channels and straits, in which the tide enters at both extremities, the tidal phenomena are so varied and full of interest, that it becomes highly important to spread the observations over as large an extent of the channel as possible, and to pursue a regular system of hourly observation throughout both the *ingoing* and *outgoing* streams.

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* The bottles, before being sealed, should be ballasted with a little dry sand, consolidated at the bottom with bees'-wax or pitch run in, that the bottle may be kept upright, and not swim too light.

It is desirable to know at each place the time of slack water, the direction in which the stream turns, and the rate and course at which it runs during its several stages. The stations should be numbered, and the times all referred to one meridian. In such channels there will probably be one or more places where the streams meet, and there, of course, observations will be made; and as one of these places will probably be the *virtual head of the tide wave*, it may so happen that the time of the high and low water there *by the shore* will govern the turn of the stream either along the whole channel or until it reaches a spot where another meeting of the streams occurs. In such a channel also it will probably be found (as in the Irish Channel) that the same stream makes high water at one end and low water at the other at *the same time*; so that the observer must entirely divest his mind of the too often mistaken notion of the turn of the stream being governed by the rise and fall of the water in its immediate locality. As our space does not admit of further detail, I shall leave the subject in the hands of the observer with a remark which, whilst it will put him in possession of what kind of observations are required, will at the same time, I think, insure his interest in the subject and his hearty desire to co-operate in the matter.

In the Philosophical Transactions, 1848, Part I.,* it has been shown that in such a channel as that above mentioned there have been discovered two remarkable spots, in one of which the stream runs with considerable velocity without there being any material rise or fall of the water by the shore, and in the other that the water rises and falls considerably without there being any apparent motion of the stream. Such phenomena are highly curious, and worthy of all the attention that can be bestowed upon the observations. In tracing them it is manifest that they are intimately connected with the height and progress of the tide wave along the shores of the channel; but this properly belongs to another article (see *Tides*).

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* This valuable paper, by the late Rear-Admiral Beechey, as well as another on the Tides of the Channel and North Sea, is annexed to the Tide Tables published annually by the Admiralty, and supplied to all H. M. ships. (W.)

9. Passing the mouths of great rivers—such as the Amazon, the river Plata, Orinoco, Mississippi, Zaire, Senegal, Indus, Ganges, Yangtsee or Irawady, &c. &c.—observations on the stream should be more closely made, and discolorations and specific gravity of the water noted.

These and such like stupendous rivers extend their influence to a considerable distance from the coast,* and occasionally perplex and delay the navigator, who finds himself struggling against a difficulty, wholly unconscious of the cause and ignorant of the facility with which he might escape it by changing his route.† River currents of this description vary their direction according to the courses of the stream along the coast, by blending with it and forming a curve, which vanishes only with their influence upon the ocean current; so that we are not always to look for the outset from the river at a right angle to the coast, nor always in the same locality, but according to the prevailing offing stream.

The limits of the principal currents of the globe have been given (see plate B) in order to apprize the navigator of the places in which he should more closely attend to his observations. If, however, from any cause he may have been prevented from continuing the series throughout any of the great currents, and should desire to define their limits, he should begin at least a day's run from the places, and continue his register until he is certain of having passed the boundaries, attending closely to the temperatures; for although limits have been assigned to these belts of moving water, yet they vary so much according to season, and the data for defining them have hitherto been so insufficient, that they cannot be said to be known with any tolerable degree of precision.

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* The river Plata, at a distance of 600 miles from the mouth of the river, was found to maintain a rate of a mile an hour; and the Amazon, at 300 miles from the entrance, was found running nearly three miles per hour, its original direction being but little altered, and its water nearly fresh.—*Rennell, Sabine.*

† See the effect of the Equatorial and Guinea currents before mentioned, at p. 17.

In the China Sea and among the islands of the great Indian Archipelago the tides run strong, and are very indifferently known, and observations are especially desired at those places.

In the southern passages it would be well to try, during the westerly monsoon, whether the equatorial current may not be found pursuing a subaqueous course to the westward, notwithstanding that the surface current be found running in the opposite direction.

Upon the east coast of North America, between the Gulf-stream and the coast, observations upon the set of the stream are also much wanted.*

Approaching a Coast.

10. When approaching a coast or any extensive banks in the ocean, the temperature of the surface of the sea should be more closely attended to, for it has been found in many instances that, after a certain shoaling of the water, the surface partakes of the temperature of the lower strata of the sea, which are in general colder than the upper. If such should be found to be the case always, and if from well-authenticated facts it should become possible to fix zones of certain temperatures about particular localities, the result would be highly useful to the navigator when out in his reckoning and perplexed with thick and hazy weather.

11. Hydrography requires that the general feature and

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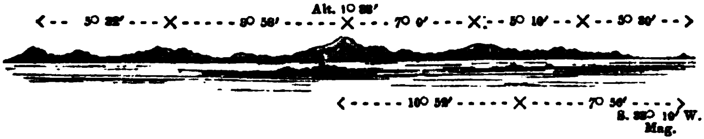
* The American Coast Survey has now supplied this want. See on this subject some valuable remarks by Maury, in the 'Physical Geography of the Sea.'

aspect of every country should be noted from the moment the hills rise above the horizon; that all remarkable objects by which it may be recognised and by which the position of any port or other locality may be known, either at a distance when the weather is clear, or close in when haze or mist prevails, should be described as graphically as possible; that the extent, direction, and outline of the coast—its capabilities of affording shelter to shipping—its dangers or freedom from them—its navigable rivers, harbours, and inlets, and the objects adverted to under *Sailing Directions*—should be fully and carefully recorded; and here it is difficult to avoid infringing upon what properly belongs to *Geography*. The two sciences are, indeed, here so nearly allied, that it is scarcely possible to avoid encroaching upon the province of the sister branch. The observer will, however, do well to describe or delineate the character of the country as far as he can become acquainted with it; the form and elevation of such hills as are visible from the coast—the direction of the valleys and ravines—and to mark the places where they pour their mountain-torrents into the sea; to portray the bold topping cliffs, or the low rocky promontories and their reefs—the jutting headlands or deep sinuosities, or the low undulating country with its lagging streams and muddy or sandy fringe of coast; its shallows, bars, and deltas, each as the case may be—with its lighthouses, beacons, buoys, and landmarks, stating the distances at which they may severally be seen—with even the forts, towers, churches, and silvery little clusters of cottages upon the inland elevations—with such other varied features as the coast may present, and as may serve to convey a just idea of what may be expected to meet the eye of the navigator, or be required to keep him clear of danger and to guide him in safety to his place of destination.

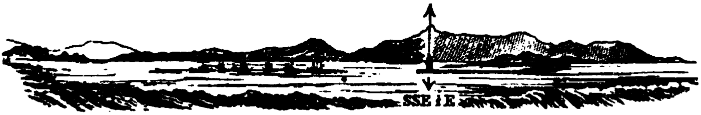
At a distance there is generally some object more remarkable than another which may be singled out as a useful landmark. Note what it is, describe its appearance, and state in what direction the port, or any danger that may lie off the coast, bears from it.

Should the coast be low, buildings will possibly be seen first: large square houses or towers, church-spires, &c.—any of these afford useful guides. Some localities may be distinguished in hazy weather by *patches of white* near the coast, such as masses of sand, chalk cliffs, &c., or one or more large white houses; and these, when viewed against the land or other dark objects, will occasionally afford excellent guides when all other objects are obscured, and at such times are doubly useful. But avoid as marks all *white* objects which have only the sky for a background; such objects are seen only when the sun shines upon the surface presented to the observer, but utterly fail in *hazy* weather, when they are wanted.

Always bear in mind that no description can equal a tolerably faithful sketch, accompanied by bearings. In all your sketches take angles roughly, with a sextant between objects at the extremities of your drawing, and two or more intermediate ones, and affix them to the objects at the moment, and have at least one angular height in the picture; let that be of the highest and most conspicuous or best defined object, thus:—



and let your bearing refer to one of the objects between which you have measured angles. Always write under the sketch at the time the name of the place, and especially the native name, if you can possibly learn it, and the date; and if you intend any of the objects for leading-marks, place an arrow at the head of a perpendicular line above and below them, thus:—



Lighthouse in one with East Peak of Mount Auckland, clears reefs in 4 fathoms, and kept open (S. by E.), leads through the passage, mid channel.

12. Besides marks which are apparent to the eye, the depth of the water and the nature of the bottom are all important; and in all descriptions of a coast, as well as in directions for approaching it, these are to be carefully attended to. State as nearly as possible the distances at which certain zones of soundings extend from the shore, and from what part; whether the bottom shelves gradually or abruptly—whether the coast may be boldly approached, or more than ordinary caution be necessary—and whether any peculiarity of the bottom may assist in determining a ship's position or distance from the coast at night, or in thick weather. Always give your depths reduced to low-water spring-tides if possible,* and always give *the least water* upon a reef or shoal; and if it dries, state what water there is over it at high-water springs, and at what time of the tide it becomes dry.

13. When nearing a coast, and at all times when at a *greater distance from the shore in miles than the amount of dip in minutes due to the height of your eye*, the height of mountains or of other objects may be determined with considerable accuracy if the weather be clear and proper precautions be taken. To do this, if the distance of the object be not known, it must be found by measuring a base with the patent log. There are various methods given in navigation books for determining this problem; I shall, therefore, here merely describe the observations required to be made. At each end of the base measure carefully with a sextant the altitude of the object *off and on;* and if one of Cary's double sextants be on board, measure the terrestrial refraction by bringing the opposite horizons in contact with the arc both above and below the index, and then, reading off each time, divide the difference by 4; this will give the dip and terrestrial refraction combined, which is the proper quantity to be allowed in correcting the observed angle.†

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* See page 38.

† If the terrestrial refraction alone be required, take from this quantity the true dip due to the height of the eye, and the remainder is the terrestrial refraction required.

In Raper's 'Navigation,' p. 90, 2nd edition, the method of determining a ship's distance from an object by two bearings is briefly explained; and in Belcher's 'Surveying' it is set forth in a manner so clear and ample as to leave nothing to be desired: I shall, therefore, merely observe here, that, according to the accuracy of the observations and the value of the means adopted, will be the correctness of the result. It is clear that the *true* bearing of the object at *each* station should be observed (see Astronomical Bearing); that the course steered should, if possible, be equally well known (this is effected in the best manner by observing the magnetic bearing of the object with the compass which directs the base, or that which is to be steered by in-running the base, *at the same time that its true bearing is observed*); that the distance run should be determined by patent log—that the ship *should be on her course at starting when the bearings are observed*—and that the log should be put over and hauled in at the *instant of making* the observations. If the ship should of necessity alter her course during the operation, it should be carefully noted, the log looked at, and fresh bearings of the objects taken.

Two observers are necessary to accomplish these observations nicely, and without hurry.

With these data the height of the object may be found with considerable accuracy, especially if the dip-sector be used.* Having determined the height of a mountain, you may often find it useful to know your distance from it when cruising off the coast; and it will also afford amusement and practice to see how near you can fix the ship by it, as compared with cross-bearings or other observations. For this purpose it will be convenient to make a constant for the height.†

Lighthouses.

14. If lighthouses are erected upon the coast, describe exactly their locality, geographical position, appearance,

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* See Appendix No. 2.

† See Appendix No. 3.

height of the lantern above mean water-level, height of the tower, whether the light be fixed or revolving, intermittent, coloured, or otherwise, the distance at which it may be seen, and the bearings on which the light is visible. If the light be made use of for the purpose of avoiding any danger, state what the danger is, and give its bearing from the lighthouse; and if the light be blinked or changed for this or any other purpose, state what it is, and give the exact bearing on which the change takes place.

If there be a *lower light* in the tower for this or any purpose of tide-work, state as before the bearing on which it opens and obscures, or the times of tide when it is exhibited and extinguished, and how many feet it is below the upper light. State whether pilots are required for the port, and where they are likely to be met with, and the rate of pilotage.

In Port.

15. When at anchor give the depth of the water, nature of the ground, and whether any precautions are necessary with respect to protecting the cables if hempen, and whether it be proper to moor in consequence of the difficulty of keeping a clear anchor, or from the treacherous holding or sloping of the ground. Fix the spot by cross-bearings of conspicuous and well-known objects, and note the direction and rate of the tide, and the duration of both ebb and flood stream.

16. The geographical position of a port will necessarily occupy the attention of the persons in whose hands these remarks may be placed, and by assiduity much may be done in a short time with a sextant and artificial horizon only. But if to these be added a transit-instrument and a good achromatic telescope, the longitude by occultations, moon-culminating stars, and eclipses of Jupiter's satellites, will form a valuable addition to that by observations of lunar distances with the sextant.

The earliest opportunity should be taken of determining the error of the chronometers upon mean time at the place, by morning and evening sights, or by *equal altitudes*, which is better. Chronometers will sometimes change their rates on the transition from a passage in which they have been constantly in motion to a state of rest. Besides which, early sights afford a longer interval for rating the watches again.

Survey of a Port.

17. A survey of the port and description of the anchorage will always be desirable if carefully made. If former surveys have been executed, it will afford a useful comparison, and detect alterations of the banks and channels, and the silting up of the port, if any. If they have not, such a survey will be doubly useful, and the industrious observer will find very few plans of ports to which he may not usefully add a few soundings or explanatory remarks.

It is not intended in this article to enter much into the manner of executing a survey, as there are several treatises on the subject which contain the necessary information; but these works may possibly not be on board; and as "golden opportunities" of acquiring a knowledge of distant ports may thus be lost, from the want of knowing how to construct a rough survey of a place, by persons who probably never contemplated the performance of such an undertaking, it may be useful to describe as briefly as possible the process. Make choice of two stations at as great a distance apart as the survey will admit of, and from which the eye can see over a considerable portion of the ground to be mapped, as A, B, plate A. Put up marks or select objects at all convenient places around the survey, so as to be able to form a network of triangles over the whole space, and include every conspicuous feature around, such as hills, cliffs, rocks, and especially objects at or near high-water mark.

18. Having decided upon these marks, as at A, B, C, D, E, F, G, &c., plate A, a base may be measured on shore if there be a convenient spot at hand; but it would be useless to devote much time to this purpose, for the survey of a

port in general does not so much require that the absolute distances between places should be *accurately* known as that the *angles should be carefully observed*, and therefore the relative distances preserved. If it be necessary to measure a short base of a quarter or half a mile, and the ground be uneven, plant staves (boarding-pikes) in the line to be measured, and stretch the lead-line along from pike to pike in the direction of the wire of the theodolite when levelled, and measure along the line with a tape, or with rods; then shift the pikes and line on until the required distance has been measured, the length of which should not be less than 1-7th of the distance between the objects the distance of which is required.

If a micrometer be on board, a very fair base may be obtained with it,* or even with a sextant, by measuring carefully the angle subtended by a staff placed at right angles to the observer, and the distance between two well-defined marks, one at either end of the staff (such as the clean edge of a sheet of white paper wrapped round each end): the best way of ensuring the staff being at right angles nearly, is to place it upright by a plumb-line. Then, treating the figure as a right-angled triangle, the staff will be the perpendicular and the base the distance between your eye and the station, which may be readily computed, as all the angles and a side are known; but if a micrometer be used, the distance is that between the staff and the *object-glass* of the telescope. If neither of these methods be adopted, or if the field of operations be very extensive, a base by sound, though much less accurate, may be found convenient.

19. The measurement of a base by sound, if several trials are made and the distance be more than a mile, will, in most cases, be sufficiently exact for the above purposes. If possible land a swivel or small gun upon one of your stations, and go yourself to the other, the more distant the better.

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* See the Book of Tables and Directions supplied with the Rochon Micrometer.

Appoint a signal to be shown half or a quarter of a minute before each explosion, in order that the eye may rest between. When the signal is made begin to note the beats,* but not to count until you see the explosion, and then let the next beat be one, and so count up until you hear the report. Let this be done several times, and at the end mean the beats and turn them into seconds of time by the number of strokes your watch makes in a minute. Then, by multiplying this number of seconds by 1090, and adding *one foot* for *every two degrees* of the thermometer *above freezing-point*, you will obtain the length of the base in feet.

To give *a direction* to the base, the readiest way is to observe the passage of the sun's limbs over the wires of the theodolite nicely levelled, and to note the time by a watch, or to take corresponding altitudes, in order to compute the azimuth. If you have only a sextant, astronomical bearing will be found convenient and sufficiently correct, provided the horizon can be seen at a sufficient distance. By either of these methods the angle between the base and the limb of the sun will be known, and hence the true bearing of the object obtained; or, if the magnetic bearing of the object be observed by an azimuth compass, and the variation be determined at the same time, it will still be known near enough for the common purposes of navigation. Having arranged the direction and length of the base, at A and B alternately measure angles between the base and all the stations, taking care that the angles (if measured with a sextant) are as nearly as possible parallel with the horizon, and at all other convenient stations do the same. By this means the relative positions of all the stations will be obtained, from any *three* of which the position of another, or of a boat for instance, may be determined by measuring two contiguous angles between them with a sextant. But whenever you have occasion to do this (and in sounding there is no more convenient method of fixing the place of the boat), be careful not to select stations which lie in a curve *concave*

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* The stop-watch by Mr. Dent is very convenient for this purpose.

towards you, since cases will often arise when stations so situated will give very inaccurate results, as with the objects A H I at P in plate A.

20. While operations on shore are going forward, boats can be sounding out the harbour, and fixing the points of reefs, rocks, &c., bearing in mind that it will always be found more satisfactory to land upon every rock or point, &c., than to lie off in the boat, and fix them by estimated distances or by intersections, either from these or from other stations.

In sounding, fix the boat at starting by two sextant angles; note the direction in which it is intended to run out the line of soundings, and note any two objects distant from each other, that are *in a line* upon that bearing, or, if the port be not too extensive, make use of staves with flags —shifting them along the coast at the end of each line of soundings the exact distance it is intended to run them apart—the boat showing a signal when the flags are to move; then keep the marks on, and sound at regular intervals 6, 5, 4, 3, 2, or fewer casts in a minute according to the depth; and at given short intervals note the time and fix the position of the boat by two angles as before mentioned,* as also whenever there is any material alteration in the depth, or whenever the number of casts alters in a given time. When arrived at the end of the line fix the boat's position, and alter the course, sounding all the time until far enough for running back the second line of soundings parallel with the first. Fix the boat's station here again, and take a new leading mark. If the eye cannot catch a leading object at the moment, drop the grapnel to maintain the spot, for much more time is lost by over-running the lines than by coolly waiting for a guide to direct the course. Proceed in this manner, running all the soundings in parallel lines or nearly so, until the anchorage is all sounded out.

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* See the form in Appendix No. 4 for entering these angles and soundings.

Having mapped all that is intended to be comprised in the survey, protract the work carefully on board upon a sheet of drawing-paper. Draw in the coast-line, rocks, shoals, hills, &c., and every other feature from your rough, attending to the hydrographic method of delineation represented in plate A.

21. The soundings follow next, when reduced to the low-water standard of the port by the tide gauge. (See 24.) If there be no station-pointer on board, protract the angles upon a piece of transparent paper, and mark the stations with their proper numbers. If the soundings have been taken equally, divide the spaces between the triangles into as many parts as there are casts, and fill in the corrected soundings in the order in which they occur. All soundings which may have been taken when the tide was up and by reduction to low water are *dry*: *draw a line under*. In every chart-box in the service will be found the abbreviations adopted in Admiralty Charts; these are to be strictly followed, and in Appendix No. 11 are given a few symbols which will be found useful in taking angles, &c., and in other surveying operations; and in plate A are given the usual hydrographic delineations of banks, cliffs, shoals, &c.

Lastly, put a meridian line and scale to the plan. Insert the variation, geographical position, time of H. W. F. and C., the low-water standard, *to which the soundings are reduced*, and the range at springs and at neaps; note the duration of the ebb and flood, both by the shore and by the stream; draw leading marks, and put in views, heights of mountains, &c.

If time does not permit of a regular survey being executed, still a useful record may be made by an itinerant survey, or even an eye sketch, assisted by sextant angles, a few soundings judiciously taken, the true bearing of one object, and the measurement of a base by sound, or with a Rochon micrometer as before mentioned.

Sailing Directions.

22. Whenever a survey is executed, *sailing directions* should accompany it, and too much care cannot be bestowed upon this important part of a surveyor's duty.

They should contain a description of the coast (*see* 11); directions for making the land; for approaching, and sailing into or out of the port both by daylight and with the aid of marks, and also by night or in thick weather, when the lead and the lighthouse, if there be one, must be the seaman's principal guide. How a vessel is to proceed with a leading or a beating wind, and with or against the tide—how far she may stand on either tack—what water she may expect to find at low-water springs—and how she may ascertain the depth by calculation on any other day—within what limits a vessel may safely steer in bad weather and when no pilot is on board—where the best anchorage lies, the depth in which a vessel should anchor, and directions for bringing up;—with other particulars which have been mentioned under the heads of approaching a port, especially noting all beacons, buoys, lighthouses, and landmarks, &c. (*see* 11).

To these affix views of the land and sketches of the leading marks, the geographical position, the time of H. W. F. and C., rise at springs and neaps, the low-water standard of the port, &c., and the variation of the compass; point out the best watering-places, and let all bearings given be *magnetic*, and noted as such.

Port regulations and quarantine laws will not be misplaced at the end of these directions.

Tide Pole.

23. When a survey is determined upon, a tide-gauge should be set up, and from *half an hour before to half an hour after every high and low water* the place of the tide should be registered *every ten minutes.*[*] In addition to this, *whilst the*

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[*] See Forms Nos. 6 and 7.

sounding of the port is in progress, the place of the water must be noted every half-hour to facilitate the reduction of the soundings to the low-water standard. The tide-gauge should be fixed in a well-sheltered spot, with its zero at such a depth as to ensure its being below the low water at springs. When the pole is properly secured and settled down, paint a mark in the rock corresponding with one of the divisions on the gauge, and *note which* in your book, in case the pole should be washed down. If you remain long enough in port, let your observations be continued at least through an entire lunar month. When you come away, mean the high and low water heights of each day, and take a mean of them again for the *mean place of the water*, and cut *a mark in the rock corresponding with that mean level of the sea before you remove the pole*. As this is the true scientific level of reference in all matters relative to the tides, refer this level again to some mark in a contiguous building, that a reference may at any time be made to it, by persons who might not be able to find the rock.

Let the watch be always at *mean time* at the place. The high and low water observations should be continued night and day with equal carefulness in order to determine the amount of diurnal tide; and every observation should be recorded, although it may not seem to agree with the others.

If tides are taken at coral islands, or at stations within a belt of coral, it should always be noted in the journal whether the sea or land breeze be blowing, and with what strength, and also whether the surf be high upon the reefs and sending its water into the lagoon, filling it faster than it can escape.

In the Appendix will be found two forms, one of which (No. 7) is for registering the tides every half-hour, the other (No. 6) is for the high and low water only.

For further information upon *the tides* see the next article.

Soundings.

24. Before any soundings are inserted in the chart they

should be reduced to *a standard* obtained by meaning the three or four successive lowest waters of each spring-tide, and meaning them again for a general mean. This standard should be noted in a very conspicuous and *unmistakeable* manner as being so many feet below the mean water level, and recorded as the *low-water standard of the port*. It is a quantity which would nearly correspond with half the range of an *ordinary spring* tide, a term often written without any direct reference to the low-water standard, and so ambiguous that it is to be hoped it will soon disappear from the face of our charts. With this standard, and the known daily height of the tide above mean water level, soundings taken at any hour may be prepared for comparison with the depths upon the chart by the simple formula

$$R + r \,.\, \text{cosine}\left(\frac{t}{D} \,.\, 180^\circ\right)$$

Where R = the low-water standard to which the chart is adapted.
r = the height of tide for the day above mean water level.
D = the duration of the tide.
t = the time from high water previous.

Or, enter the traverse table with the time from the nearest high water as *a course* (allowing 5° of arc to every 10 minutes of time), and with r = (half the range of tide for the day) as a *distance;* in the *latitude column* will stand a quantity which, applied to the *low-water standard of the port* + or −, according as the arc is *less* or *greater* than 90°, will give the reduction required. If the arc exceeds 90° take its supplement. But it is to be observed that all these corrections, although preferable to the old method of reducing soundings, are but approximations. In many places, especially in such as have great tides, it is necessary to distinguish between *rising* and *falling*.

In a country subject to earthquakes, carefully watch the tide-pole during and after the shock; and if any undulations of the water are observed, note them, and the direction whence they proceed.

Be careful never to place the tide-pole at the mouth of a river, and especially guard against having it within *a bar*, sand-bank, or any such impediment to the free action of the water.

The Bore.

25. If any place should be visited by that peculiar phenomenon, the bore, a wave which in some places comes rolling in with the first of the flood, with a crest foaming and rushing onward, threatening destruction to boats and even to shipping; note the time of the tide at which it begins, whether there be *one wave* only or more, the height to which it rises, and *where it first* appears with respect to its elevation above or below the mean water level of the ocean, and to any alteration in the feature of the river; and especially note the situation and extent of shoals at or below the spot. It seems essential to the formation of the bore that there should be first a great rise of tide; hence the reason why this phenomenon is said to occur at spring-tides only; and, secondly, that there should be an obstruction to the advance of the foot of the tide-wave, so that the crest of the wave is rapidly overtaking it.* It is desirable, therefore, that we should determine these points by observation on every occasion which offers, for which purpose there should be carefully noted the times of the passages of both portions of the wave between two places sufficiently far apart to insure accuracy, and between which the distance, if not known, must be determined; and with these observations should always be connected the rate of the stream soon after the passage of the bore; so that the observer may be able to write down the rate of the crest of the wave, the rate of the bore, and the rate of the stream. The rise of the water will further be essential to the satisfactory completion of the observation.

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* The remark made in '*How to observe*' (p. 35,) "that either rocks or shoals, or great depth of water, secure a river from the inconvenience of the bore," is not always correct; for the Severn is encumbered with shoals, and has a bore which has proved destructive to vessels grounded upon the sands.

Freshes.

26. Connected with the rise and fall of the water is that periodical elevation of the surface of rivers by "freshes," occasioned by heavy and continued rains in the interior of the country. These torrents not only raise the general level of *the river*, properly so called, but, where a bar exists, also raise the level there, so that vessels which cannot enter during the dry season are at such times able to pass over the bar. The time when the water begins to rise, when it attains its maximum, when it begins to subside, and regains its mean or ordinary level, should be carefully noted, and with it the elevation of the water, in feet, both in its ascent and descent.

Discovery of Land.

27. On the discovery of any unknown lands or dangers, the first endeavour, after the vessel is placed in safety, should be to fix the position of the place as accurately as the means of observation admit, and not to quit the spot until the danger is satisfactorily placed upon the chart.* Describe it as accurately as you can; determine its extent, height, and configuration; the adjacent soundings, and the quality of the ground; and give a sketch of its outline. If it be extensive, a running survey will be desirable.† If it be within sight of other land, its position must be fixed by bearings or angles between known points of the coast, and some conspicuous objects upon the land selected, which being *brought in a line* will lead ships clear of the danger. Do this for *both sides*, and give correct bearings of the transits, and, if possible, sketches of the objects.

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* See Raper's 'Navigation,' 855, p. 328; and 856, p. 329. "No commander of a vessel," observes that talented officer, "who might meet unexpectedly any danger (before unknown), could be excused, except by urgent circumstances, from taking the necessary steps both for ascertaining its true position and for giving a description as complete as a prudent regard to his own safety allowed."

† See *Running Survey*, No. 29.

As regards coasts and islands which are but little known, there is given in the Appendix a list of such as are most deserving of attention, extracted from a return made by the able and indefatigable officer* at the head of the Hydrographic department to an order of the House of Commons, 1848;† and all general directions for acquiring information which may have been already given must be considered to apply with double force to these countries. The limits of this paper do not permit of our entering into particulars as to the probable position of places which may be imperfectly determined, nor of the reported position of islands which are considered doubtful. In the Atlantic alone, for instance, there are islands reported continually where none could possibly exist; and the islands of the Pacific have been multiplied by the errors of longitude made by persons visiting them; but wherever the charts place any islands as doubtful which you wish to seek (as it is always more probable that the latitude is correct than the longitude), the *parallel* of the supposed latitude should be gained at a meridian sufficiently distant from that given to exceed the probable limit of error in longitude, and a due east or west course pursued until a similarly distant meridian is gained on the other side; and if there should be any change in the colour of the water, sounding ought by all means to be tried; and especially we call attention to soundings upon the site near the equator marked as the seat of volcanic action from about 3°½ S. and 15° to 24° W., and also to the vicinity of the great bank S. and S.E. from the Falkland Islands, called Burdwood Bank, on which there has been found recently as little as 24 fathoms; also to the Agulhas Bank, and the sites of any volcanic islands which may have risen and disappeared.‡

Sailing along a Coast.

28. Even when sailing along a coast or islands which may be known and charted, it is advisable, as a general

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* The late Rear-Admiral Sir Francis Beaufort, K.C.B.

† Now brought down to the 1st January, 1859.

‡ See also 4.

practice, to *verify* the position of the points and headlands as the ship sails along; and when the coast is new, or but indifferently explored, no opportunity should be omitted of determining as accurately as possible the position of every part within your power.

The position of places is determined from a ship with the least disadvantage, by being brought to bear east or west when the latitude is taken, and north or south when the longitude is observed. And as these observations may be made during several hours of the day,* much may be done in a single day's run, especially if patent log bases connect the stations, and astronomical bearings be employed. And upon all occasions the noting of transits, or the coming in a line of remarkable objects and of points of interest, should form a necessary portion of our duty, although we may believe them to be already satisfactorily determined, as they afford the most critical test of the accuracy of former surveys, and are especially useful in cases where longitudes of contiguous places may have been obtained by different observers.

If time admits of more than this being done (and in some of the countries which are but little explored it is extremely desirable that no opportunity should be lost of perfecting their outline), the heavy boats may be hoisted out and sent in-shore of the ship to run in the coast-line and the detail whilst the ship carries on a triangulation and continuation of bases in the distance, making what may be termed a running survey.

Running Survey.

29. Whenever this can be done, send the boats to a distance of 4, 5, or 6 miles at starting, and let them and the ship anchor, if possible, to measure a base by sound (19), and to get astronomical bearings and angles to the *same points.* Fix the ship's position by repeated observations for the latitude and by chronometer; then weigh and

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* See Raper's 'Navigation,' 830 et seq., p. 320; also 834, p. 321; second edition.

put the patent log over and steer a steady course along the land (sounding, if the depth of water admit of it, without stopping). One boat now runs along the land from point to point, putting in the coast-line and its detail, getting astronomical bearings and angles as she proceeds, especially of all transits of points and headlands, and measuring her distance between them by patent log, and sounding, but without stopping. The other boat attends principally to the soundings, fixing herself as she requires, by angles and bearings between the points determined by the other boat and the ship.

At the end of a few miles' run, or at noon, or when necessary to renew the angles and bearings, a signal is to be shown, and the logs are then to be hauled in and read off, but not reset, fresh angles and bearings to be taken and a new base commenced, the distance between the ship and boats being again measured by sound. The log is then again put over, and the course of the vessel resumed. In this manner the day passes, the bearings and observations all being worked out at the moment—the outline run in, views taken, and every particular mapped and booked at the time, so as to leave nothing to memory. At the close of the day's operations anchor in position, measure a base by sound, and repeat operations as at starting, recall the boats, and in the grey of evening get the ship's position by stars and planets, which may at this time be observed with great accuracy before the horizon becomes too obscure. If the ship can remain at anchor, she will observe the set of the stream and the rise and fall of the water, however roughly it may be done.

As early as possible commit the triangulation to paper, that the ship may start in the morning with some points of land well fixed, so as to enable her to continue her triangulation throughout the day without the aid of the boat, although her co-operation as before should be renewed.

If there be no anchorage, the ship will maintain her position during the night under canvas, and in the grey of the morning picking up the place where she left off on the preceding evening, send the boats away, get altitudes of stars for latitude and longitude, measure a base by sound, get astronomical bearings and angles, &c., and putting over the patent logs continue along the coast as before.*

Thus far we have considered the observations as being wholly confined to the vessels, but it will add considerably to the accuracy of the survey if landings be occasionally made, and the stations be critically determined by astronomical observation, *i. e.* by latitudes and chronometers, and the positions connected with the rest of the work.

30. It is not necessary to be provided with a regular chart for this purpose; the projection may proceed as you advance. Thus, consider how the coast runs, and draw a line along the paper to represent the meridian at starting; set off on this a degree of latitude according to the scale on which the survey is to proceed, 1 inch or 1½ inches to the mile, or more or less according to circumstances, and begin at once to lay off the bearings and angles. As you take up other stations, proceed to throw out meridians and parallels in the manner described in Appendix No. 9. A chart upon this projection will be found easy of construction and more satisfactory than any other; and, when the survey does not extend over more than 8 or 10 degrees of latitude, it is sufficiently correct. In laying off bearings upon it, it must be borne in mind that they are to be projected with reference to the meridian passing through the spot. Mercator's projection, in which the meridians are all parallel, and which is in such general use in the navy, except in very low latitudes, is not adapted to the purposes of a survey, as the bearings and the protraction will never agree together, nor with the observed latitude and longitude of the stations.

With reference to the longitude, I may remark that the absolute longitude of the place is not required, but it is necessary to determine the *difference of meridians* as you proceed; and these should afterwards be compared with some well-determined meridian. I may observe here, once for all, that the longitude of a place, by chronometer, from Greenwich, should never be given without the *accompanying longitude from which the deduction of the meridian was made;* in short, that chronometers should be referred to only as a *measure of* DIFFERENCES.

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* For further information, and a more extensive application of this method, see Belcher, Mackenzie, and other works on nautical surveying.

Coral Islands.

31. Should coral islands be fallen in with, determine their position and extent, and map their outline; fix the openings into the lagoons, and describe their general appearance, whether wooded or not, and whether any high clumps of trees (distinguishing the palms) be conspicuous upon them, and at what part; you should then particularly notice the slope of the coral both on the outside of the island and the inside, and run off lines of soundings in various parts from the water's edge to as great a depth as you can reach, and at each cast particularly note the bottom, whether it be living or dead coral: note the greatest depth at which live coral is brought up, as the existence of living coral at great depths is a point of interest. A swab fixed to the lead will often bring up specimens of coral which might otherwise be missed.

Point out the place of the anchorage in the lagoon by an anchor, and state whether vessels can sail in with the trade wind or not, and the best time for going in, for in many of these islands there is so strong a current running out through the channel after the trade wind has set in, in the morning, as to render it imprudent to attempt the passage; and in some it is only after the sea wind subsides, and the land breeze has commenced, that the passage can be effected. It is the sea getting up with the breeze and beating over the reefs into the lagoon that occasions such a current through the opening. Inquire into this on the spot, and do not commence any tide observations in the lagoon if the reefs are low and the channel small: if, however, the lagoon be open on one side and sheltered on the side of the prevailing wind, these spots in the ocean afford excellent places for observations upon the tides.

Currents occasioned by the trade wind prevail about all the islands situated in those latitudes; their direction and force should be ascertained and stated in your remarks.

Rivers.

32. All rivers should be traced to the farthest possible point that time will allow; for, although it is the usual practice to limit hydrographic inquiry to the vanishing point of tidal influence, yet there are many reasons why we should not here so circumscribe our views. Rivers are the great arterial features of our globe; they define the valleys, give boundaries to the hills and mountain ranges, and if traced to their source enable us, with the aid of a few well-determined culminating points of contiguous ranges, to trace upon our charts the general feature of the country through which they flow. Besides which, they are so far connected with the navigation of our ports and harbours, that their aid is often indispensable to a free access and egress, by affording a powerful means of scouring channels and removing impediments to shipping, which would otherwise be denied admission. They may, therefore, be said to be of almost equal importance to hydrography as to physical geography. In all cases, then, where rivers approach or flow into any of the ports under examination, you should acquire as extensive a knowledge of them as you possibly can, map as much of the windings and features as is practicable, and especially of such parts of those that are not navigable as may be made available to the improvement of the navigation of the port, or in any way be converted to hydrographic use, particularly noting the depth, extent, and variations of surface, of all widenings of the stream, or basins affording back-water and capable of being retained or converted to a scouring power, carefully determining the elevation of the surface above the *mean level of the ocean*, and, if the river does not run into the port, whether it could not be conveyed to it, and with what facility. These inland basins are occasionally greatly affected by mountain torrents, melting of snow, and rainy

periods, raising their surface to an extraordinary height even in a few days; while, on the other hand, long dry seasons depress them as much below the mean level. Our endeavour should be to ascertain these variations and the mean level of the water of the basin; we may often see, for weeks after the event, the mark of the wash of the water around the lake or basin far above the existing level; this may be measured and compared with the place of the mean level, and be coupled with the place of the water according to the best information to be procured at the place (noting the informant).

Note the depth and capability of transport or of inland navigation, and the power of traversing the stream for military purposes; also the nature and peculiarity of construction of the vessels employed and the means they have of advancing against the stream, &c., and the distance to which navigation is practicable, severally for vessels, boats, or barges.

In large rivers communicating with the sea, note the facility of access and egress, the depth of water on the bar, if there be one,* the position and nature of shoals or rocks, and the navigable capabilities of the stream, the rate and duration of flood and ebb, that is, of the *ingoing* and *outgoing* stream; the distance to which the stream runs up, and the extent to which the rise and fall of the water is felt, or what may properly be called the end of the tide; and here always, if possible, determine the elevation of the high-water line above the *mean level* of the ocean.

Lastly, in speaking of rivers, let it be understood that the *right* or *left* bank should have reference to the *downward direction* of its course, so that, when descending the stream, the *right* bank is on the *right hand*, and *vice versâ*. It is better to adopt this phrase than to say east or west, which might at the least be ambiguous, for it is clear that if a stream meander much, its course being always of necessity downwards, it might be successively diverted to every point of the compass.

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* What has been already said on leading marks, lighthouses, beacons, buoys, &c. &c., of course applies here also.

Lakes.

33. Lakes, properly so called, or which have no rivers running through them, can scarcely ever be turned to the uses of hydrography except when they are upon a level with the sea, when a communication has been or may be made, and a scouring power obtained by the admission of the tide through the port. However, what has been said of river basins may be applied to these enclosed sheets of water. The principal points are, their distance from the port, height above mean water-line of the ocean, depth, dimensions, and fluctuation of surface, the quality, temperature, and sweetness of water, the nature of the bed and borders, inland navigation if any, &c.

Artificial Harbours.

34. In all harbours, but especially in the vicinity of those which are formed by piers carried out into deep water, it is proper to notice whether there are shoals formed about the piers and the pier-heads especially. If there are, obtain information as to the probable cause, when they were first noticed; carefully note their extent and direction, and connect with them the direction of the tide, ebb and flood; and if there be any stream through the piers out or in, note its rate, direction, and the distance it extends. The form and construction of artificial harbours, piers, and breakwaters, does not properly belong to hydrography; but it may be well to describe and record the form of the breakwater, the pitch or slope of the stonework, *the depth* in which it is erected, the material of which it is composed, the nature of the work, and how it has resisted the sea. Or if there be an opportunity of seeing it in a gale of wind, note the power which any peculiar form or construction of breakwater may have in repelling a heavy sea, or the effect which any peculiar form of pier may have in diverting the sea at the entrance from the anchorage within; the position of the entrance with regard to the offing-stream and prevailing wind, the width of the channel,

the protection of the anchorage, the number of square acres enclosed. If there be any backwater, state its extent, how the scouring, if any, is managed, at what time of tide, and what is its apparent effect; and at all places wherever backwater is used, it may be as well to sound off the mouth of the port to as great a distance as the effect of the scouring action can possibly extend, for occasionally injurious effects have been produced by this powerful agent at a distance scarcely contemplated. State all deposits, siltings up, and at what rate they proceed.

Foreign Ports.

35. In visiting foreign ports, a particular account should be given of the resources of the place in the event of vessels requiring either a repair or a refit. Such as whether there are any docks, wet or dry? what sized vessels they are capable of receiving, and how many at a time? is there a patent slip or gridiron? &c. How near vessels, of particular dimensions, can approach the wharfs, or at what time of tide lie alongside of them; whether there are sheers for removing masts, and of what size, or cranes for lifting machinery and boilers; whether there be a dockyard or arsenal, or whether stores can be procured from other sources? Whether there is a steam-yard, and to what extent they cast and manufacture machinery or boilers, or can repair steamers?

Whether there is a coal-depôt, and what quantity of coal can be generally relied upon as at hand; the nature and quality of the material, &c.

Are there any piers, jetties, or wharfs for landing passengers, or cranes for carriages, and at what time of tide available? If the country be low, are there any sea walls, and would the country be flooded by their removal?

Waves.

36. Lastly, the attention of the observer should be directed to the measurement of the height, the extent, and the velocity of the waves of the ocean;—not only of those

high swelling seas which are common to every gale, but especially of those gigantic ridges which are occasionally met with off Cape Horn, the Cape of Good Hope, and even in the Atlantic, coming in couplets and triplets in the course of a gale, and occasioning fearful lurches which are long remembered. Opinions differ greatly as to the dimensions of these stupendous bodies, and any observations which will assist in determining their limits cannot fail to be acceptable. The inquiry is, *first*, as to the height of the solid wave above the mean water-level. *Secondly*, the distance of the ridges apart. *Thirdly*, the rate at which the wave travels, and whether the height and distance of the ridges vary with the velocity. *Fourthly*, what is the greatest estimated extent of any one of those ridges.

The most simple way of measuring the height is, when the vessel is in the lowest part of the trough between two following seas, to ascend the rigging to such a height as will bring the top of the wave on with the horizon, to put a mark, note the inclination of the vessel, and *at leisure* to measure the perpendicular height of the eye above the water-line, which we may presume will be double the height of the wave above the mean water-level. It will necessarily require several observations to be made before any satisfactory conclusion can be arrived at. The distance of the waves apart may possibly be tested by actual measurement, by means of the lead-line and a float veered out to such a distance that the float shall be on the crest of one wave when the ship is on the top of the other; and the rate may be determined by the time occupied by the wave in passing from the float to the ship: the rate of the ship through the water, and the angle her course makes with the route of the wave being known. There are other methods of solving this interesting problem which will, no doubt, occur to the intelligent observer, and they are sufficiently numerous to afford ample exercise of his ingenuity, but all are attended with difficulty, owing to the circumstances under which the observations are required to be made.

APPENDIX No. 1.

DATE.	LATITUDE.	LONGITUDE.	CURRENT.		VARIATION.	WIND.		TEMPERATURE.		BAROMETER.	REMARKS.
	N. or S.	E. or W.	Direction.	Rate.	E. or W.	Direction.	Force.	Air.	Sea.		

Remarks upon the Currents which prevailed in the passage across the Atlantic.

"From the time we quitted Teneriffe, with the N.E. trade wind, until we lost the breeze in lat. 7° 40′ N., long. 26° 40′ W., the current set on an average S. 54° W. true, at the rate of 11½ miles per day. On losing the trade and entering the calm latitudes, the westerly current ceased, and the next 24 hours the ship was set N. 83° E. true 23 miles. The meeting of the opposite currents was marked by a strong ripple, which was traced to a considerable distance. The four succeeding days, in which we changed our position from lat. 7° 20′ N., and long. 26° 58′ W., to lat. 3° 56′ N., long. 26° 44′ W., the current ran S. 70° E. true 13 miles per day. Here we met the S.E. trade, and with it experienced a strong current, which carried us N. 62° W. true 23 miles per day, until we made Fernando Noronha. Hence to a position 100 miles due E. of Cape Ledo the current set between S. 78° W. and S. 21° W. (true) on an average daily rate of 27 miles," &c.

"While in Rio Janeiro H.M. ships A. and B., the packet C., and a fast-sailing schooner the D. arrived, and we learnt that the A. had crossed the equator in 18° W., the B. in 25° W., the C. in 29½° W., the D. in 39° W., whilst we crossed in the E. in 30° W.; and upon inquiry it appeared that the passages from England were as follows, viz.: the A. was 49 days, B. 40 days, C. 38 days, the E. 36 days, and the D. 110 days, having got *so far to the westward that she could not weather Cape St. Roque*, and was obliged to stand back to the variable winds to regain her easting. Thus it appears that, with the exception of the D., *the passages were shortened in proportion as the equator was crossed to the westward*," &c. &c.

APPENDIX No. 2.

TO FIND THE HEIGHT OF AN OBJECT THE DISTANCE OF WHICH IS KNOWN.

Rule.—To the observed altitude apply the true dip, less the terrestrial refraction;* the result call corrected altitude: to the log. of the distance in yards add the constant 8·073007, and find the log. of the sum, which turn into arc, and add to the corrected altitude; then to the log. tangent of this sum add the log. of the distance in yards, as above mentioned: the result will be the log. of the height of the object in yards.

Example.—Mount Etna was seen at 57 nautical miles, or 115,650 yards, distance, and subtended an angle of 1° 30′ 00″ with the horizon; elevation of the eye 20 feet; required the height of the mountain?

```
                      °  ″   ′
Altitude . . . .      1  30  00                 Distance in yards, 115650; log. 5·063147
   ⎧Dip . . . .       −  4   43                               Constant . . . 8·073007
   ⎪                 ───────────                                       ──────────────
 † ⎨                  1  25  17                            60)1368″ log. = 3·136154
   ⎩1/11 of Dip . .     +    26                                ───
                     ───────────
Corrected Altitude    1  25  43
                      + 22   48 . . . . . . Correction . 22′ 48″
                     ───────────
True Altitude . .     1  48  31 Tangent  . 8·4993668
                                Constant . 5·0631570
                                           ─────────       Yards.
                                           3·5625238 log. 3652 height required.
                                                          × 3
                                                          ─────
                                                          10956 feet.
```

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* The terrestrial refraction varies from $\frac{1}{8}$ to $\frac{1}{14}$ part of the dip.

† If the Dip Sector had been used the observed Dip should be substituted for these quantities.

APPENDIX No. 3.

TO FIND THE CONSTANT FOR A HEIGHT, IN ORDER TO COMPUTE ITS DISTANCE READILY FROM ITS OBSERVED ALTITUDE.

RULE.—From the log. of the height in yards subtract the constant log. 6·5424481, halve the sum, find its sine, and take out the corresponding co-sine, which is the constant required (*a*).

To find the Distance.

RULE.—From the observed altitude subtract the dip, less the terrestrial refraction,* and call the remainder corrected altitude. To the constant above mentioned 6·5424481 add the cosine of the corrected altitude, and from the cosine of the sum subtract the corrected altitude. The remainder is the log. of the approximate distance in arc. Divide the approximate distance so found by the proportion of terrestrial refraction allowed, and subtract the quotient from the before found corrected altitude for the true altitude.

Lastly, add the cosine of the true altitude to the constant due to the height of the object (*a*); find the cosine of the sum, and subtract from it the true altitude; the remainder is the distance in arc required.

EXAMPLE.—Observed the altitude of Snowdon to be, On 45′ 00″
its height being 3543 feet = 1181 yards Off 45 10
required its Constant and its Distance, height of eye
being 14 feet. 45 5 mean.

Log. of height in yards 3·0722499
Constant . . . . . 6·5424481
2)16·5298018
Sine = 8·2649009
Cosine = 9·9999265 Constant required.

To find the Distance—

Constant for Snowdon 9·9999265
Cosine corrected Alt. 9·9999686
1° 15′ 33″ = Cosine 9·9998951
− 41 20 Alt.
$\frac{1}{10}$) 34 13 Approx. dist.
3 25 Correction.

Observed Alt. . . . 45′ 5″
Dip for 14 feet . . . −3 45
41 20
Terrestrial ref. $\frac{1}{10}$ of Dip + 22
Corrected Alt. . . . 41 42
Correction . . . . − 3 25
True Alt. 38 17

Constant . . . 9·9999265
Cosine true Alt. . 9·9999731
1° 13′ 55″ Cosine = 9·9998996
True Alt. − 38 17
miles.
35 38 = 35·6 = distance of object.

---

* The terrestrial refraction varies from $\frac{1}{8}$ to $\frac{1}{14}$ of the dip.

APPENDIX No. 4.

TUESDAY, 24th. Sounding in the 1st Cutter, WILLIAM REEDER, Leadsman. Sextant used, D 56. Line correct at starting.

AUGUST 24, 1847.
(Officer's Name, Mr. D. HALL.)

Red. to L. W.	Mean Time.	SOUNDINGS. High Water h. m. 5·36 P.M. Low Water 11·42 A.M. } Range ft. in. 33 9	Course.	P. Log.	DATE AND REMARKS. Spring Range 44 feet.	Objects.	Angles.	Objects.	Angles.	Objects.
fm.	h. m.	fms.		m.			° ′		° ′	
$\frac{6}{8}$	11.45	$\angle^{1}$ $2\frac{4}{8}$ $2\frac{4}{8}$ $2\frac{4}{8}$ $2\frac{4}{8}$ $2\frac{3}{8}$ $2\frac{3}{8}$ $2\frac{4}{8}$ $2\frac{4}{8}$						$\angle^{1}$		
		Reduced $1\frac{5}{8}$ $1\frac{5}{8}$ $1\frac{5}{8}$ $1\frac{5}{8}$ $1\frac{4}{8}$ $1\frac{4}{8}$ $1\frac{6}{8}$ $1\frac{5}{8}$	Pulling in the direction of Clevedon church, tree in one with house on the side of the hill.			Denny Island.	63.46	Clevedon church.	79.11	Worle mill.
	11.55	$\angle^{2}$ $1\frac{5}{8}$ $3\frac{4}{8}$ $3\frac{3}{8}$ $3\frac{3}{8}$ $4\frac{5}{8}$ $6\frac{1}{8}$ 7 $5\frac{3}{8}$						$\angle^{2}$		
		Reduced 1 $2\frac{5}{8}$ $2\frac{4}{8}$ $2\frac{4}{8}$ 4 $5\frac{3}{8}$ $6\frac{1}{8}$ $4\frac{3}{8}$				Ditto.	61.12	Ditto.	84.18	Ditto.
1	12. 0	$\angle^{3}$ $3\frac{3}{8}$ $3\frac{3}{8}$ $2\frac{1}{8}$ $2\frac{3}{8}$ $2\frac{4}{8}$ 3 $3\frac{3}{8}$						$\angle^{3}$		
		Reduced $2\frac{3}{8}$ $2\frac{3}{8}$ $1\frac{1}{8}$ $1\frac{3}{8}$ $1\frac{4}{8}$ 2 $2\frac{3}{8}$	Altered course, and pulled towards Denny Island, in one with church.			Usk light-house.	89. 4	Walton castle	108.22	Worle mill.
$1\frac{1}{8}$	12. 5	$\angle^{4}$ $2\frac{1}{8}$						$\angle^{4}$		
		Reduced 1				Ditto.	109.21	Ditto.	71.32	Ditto.
		At 6 o'clock left off sounding and measured the line over; found it correct.								

NOTE.—The objects are here placed according to their observed relative positions, and should always be so written down: the *right-hand* angle being invariably read off *first*.

APPENDIX No. 5.

The number of Miles or Minutes of the Equator contained in a Degree of Longitude under each parallel of Latitude for the Spheroid. Compression $\frac{1}{\text{[illegible]}}$.

Lat.	Length of Degree.	Lat.	Length of Degree.	Lat.	Length of Degree.
°	′	°	′	°	′
0	60·000	31	51·475	61	29·161
1	59·991	32	50·930	62	28·240
2	59·964	33	50·370	63	27·310
3	59·918	34	49·793	64	26·372
4	59·854	35	49·202	65	25·426
5	59·773	36	48·596	66	24·471
6	59·673	37	47·975	67	23·509
7	59·556	38	47·339	68	22·540
8	59·419	39	46·688	69	21·564
9	59·266	40	46·021	70	20·581
10	59·094	41	45·346	71	19·592
11	58·905	42	44·654	72	18·596
12	58·697	43	43·948	73	17·595
13	58·472	44	43·229	74	16·588
14	58·229	45	42·495	75	15·577
15	57·968	46	41·750	76	14·560
16	57·690	47	40·992	77	13·539
17	57·394	48	40·220	78	12·514
18	57·081	49	39·437	79	11·485
19	56·751	50	38·642	80	10·452
20	56·403	51	37·834	81	9·416
21	56·038	52	37·015	82	8·377
22	55·657	53	36·185	83	7·336
23	55·258	54	35·343	84	6·292
24	54·842	55	34·400	85	5·246
25	54·410	56	33·627	86	4·199
26	53·962	57	32·754	87	3·150
27	53·496	58	31·870	88	2·101
28	53·015	59	30·977	89	1·050
29	52·518	60	30·074	90	0·000
30	52·004				

APPENDIX No. 6.

The following form of a Monthly Register of Tides, in which the phenomena of each successive tide throughout the month are presented in the order of their occurrence (the data afforded by observation being entered separate from the conclusions deduced from them by graphical interpolation and by calculation), may be advantageously substituted for the form occupying pages 102, 103, in the first edition of this work:—

Monthly No. of the tide, high or low.	Day. 18.. Oct.	Times of reading off the gauge. h. m. A.M. / P.M.	Height read off on the gauge. ft. in.	Barometer. Wind. Dir. / force. Time of slack water observed.	Adopted height, time. ☽'s preceding transit. Lunitidal interval. (*h*, *t*, ☽, *i*.)	Range of tide. Mid-water level. ft. in.	Remarks and other entries.
1 Low.	1	0 20 A.M. 0 30 0 40 0 50 1 0	3 10 3 2 3 0 3 2 3 10	in. 29·92 N.N.W. 2 0h. 20m.	*h* 3 ft. 0 in. *t* 0 h. 40 m. ☽ .. .. *i*	40 11 23 5½	
2 High.	1	5 50 A.M. 6 0 6 10 6 20 6 30	43 2 43 8 43 11 43 8 43 2	29·95 N. 2 6 0	*h* 43 11 *t* 6 10 ☽ 10 57 *i* 7 16	41 9 23 6½	
3 Low.	1	0 50 P.M. 1 0 1 10 1 20 1 30	3 0 2 5 2 2 2 4 2 11	29·70 N. b. W. 3 1 0	*h* 2 2 *t* 1 12 ☽ .. .. *i*	43 1 23 8½	
4 High.	1	6 20 P.M. 6 30 6 40 6 50 7 0	44 3 45 2 45 2 44 8 44 0	29·74 N.N.W. 1 6 30	*h* 45 3 *t* 6 38 ☽ 11 19 *i* 7 19	42 6 24 0	
5 Low.	2	1 20 A.M. 1 30 1 40 1 50 2 0	2 19 2 11 2 9 2 12 2 17	29·81 Calm. 1 25	*h* 2 9 *t* 1 40 ☽ .. ... *i*		
&c.		&c.	&c.	&c.	&c.	&c.	

APPENDIX No. 7.—Daily Tide Journal.

☽'s Transit, of 18 h. m. A.M. } ☽'s Transit, h. m. P.M. { Place. Lat. Long. Var. of Compass.

Time. Mean.	Height.	Direction of Stream Magnetic.	Velocity of Stream.	Winds. Direction Magnetic.	Winds. Force.	Weather	Barom.	Therm.	REMARKS.
UPPER TRANSIT.									
H. M. 0 30 A.M.	Ft. in.		Knots.						
1 0 ,,									
30 ,,									
2 0 ,,									
30 ,,									
3 0 ,,									
30 ,,									
4 0 ,,									
30 ,,									
5 0 ,,									
30 ,,									
6 0 ,,									
30 ,,									
7 0 ,,									
30 ,,									
8 0 ,,									
30 ,,									
9 0 ,,									
30 ,,									
10 0 ,,									
30 ,,									
11 0 ,,									
30 ,,									
12 0 ,,									

Additional Observations.

H. M. F. I.	
. 0 . .	From ½ hour before to ½ hour after H. W.
. 10 . .	
. 20 . .	
. 30 . .	
. 40 . .	
. 50 . .	
. 0 . .	

H. M. F. I.	
. 0 . .	From ½ hour before to ½ hour after L. W.
. 10 . .	
. 20 . .	
. 30 . .	
. 40 . .	
. 50 . .	
. 0 . .	

Time. Mean.	Height.	Direction of Stream Magnetic.	Velocity of Stream.	Winds. Direction Magnetic.	Winds. Force.	Weather	Barom.	Therm.	REMARKS.
LOWER TRANSIT.									Moon's Age.
0 30 P.M.									
1 0 ,,									
30 ,,									
2 0 ,,									
30 ,,									
3 0 ,,									
30 ,,									
4 0 ,,									
30 ,,									
5 0 ,,									
30 ,,									
6 0 ,,									
30 ,,									
7 0 ,,									
30 ,,									
8 0 ,,									
30 ,,									
9 0 ,,									
30 ,,									
10 0 ,,									
30 ,,									
11 0 ,,									
30 ,,									
12 0 ,,									

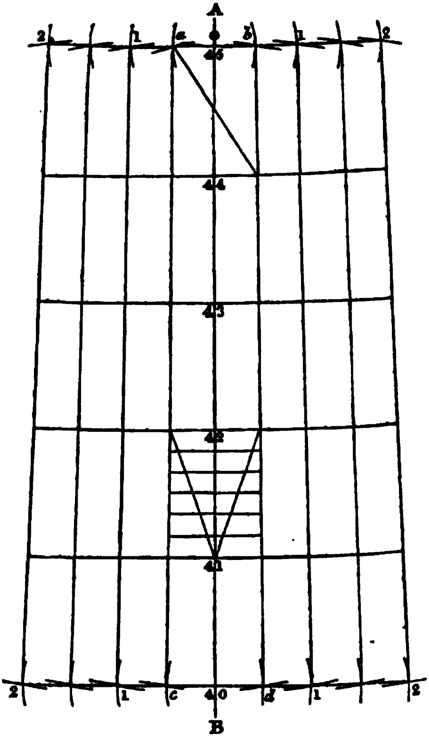
Additional Observations.

H. M. F. I.	
. 0 . .	From ½ hour before to ½ hour after H. W.
. 10 . .	
. 20 . .	
. 30 . .	
. 40 . .	
. 50 . .	
. 0 . .	

H. M. F. I.	
. 0 . .	From ½ hour before to ½ hour after L. W.
. 10 . .	
. 20 . .	
. 30 . .	
. 40 . .	
. 50 . .	
. 0 . .	

RESULTS	H. M.	H. M.		feet.	inches.
High Water at	A.M.	P.M.	Rise, A.M. ...		
Low Water at	,,	,,	Fall	,,	,,
Flood Stream terminated at	,,	,,	Rise, P.M. ...	,,	,,
Ebb ditto ditto	,,	,,	Fall	,,	,,

APPENDIX No. 8.



APPENDIX No. 9.

TO CONSTRUCT A CHART FOR A RUNNING SURVEY OF A COAST.

DRAW the meridian line A B (Appendix No. 8) through the centre of the chart, and set off the degrees of latitude upon it, of equal lengths, according to the scale which it is intended to construct the chart upon —draw short lines at right angles to each of these.

At the extremities of the degrees of latitude, as at 40° and 45°, set off right and left upon the perpendiculars distances equal to half a degree of longitude in those parallels respectively (taken from Appendix No. 5), as at *a b c d;* then with the diagonal distance *a d* or *c b*, and with the foot of the compass at 40°, sweep the small arcs 1 1 at top, and likewise the arcs 1 1 at bottom from 45°. Again, with the length of a degree of longitude in 40° cut the small arcs 1 1 before described; these intersections will be corners of parallelograms, each of a degree of longitude, extended over as many degrees of latitude as your chart contains. Repeat the process for other meridians right and left of A B, and connect the points 1 1, &c., by meridian lines. Set off upon these from either the top or bottom the degrees of latitude before laid off upon A B, and connect them all throughout the chart by straight lines, as at 40, 41, 42, 43, 44, 45, &c. For a scale, divide the degree of latitude into sixty equal parts, or into such equal portions of it as the scale admits of, and it will give a similar proportion of geographic miles of distance; and for longitude, if each degree of latitude be so divided by lines extending from meridian to meridian, and the corners of the parallelogram be connected by a straight line, as is shown in the plan between the 41st and 42nd degree, a scale of miles will be given for that parallel.

When bearings are taken they must be laid off from *the Meridian passing through the station.*

APPENDIX No. 10.

COASTS AND ISLANDS OF WHICH OUR HYDROGRAPHIC KNOWLEDGE IS IMPERFECT.

Abstract from a Return made to the House of Commons 10th February, 1848, from the Hydrographic Department of the Admiralty.

"THERE is wanted a critical examination of the eastern islands of the Mediterranean, along with the coasts of Syria and Egypt, and as much of the northern shore of Africa as would meet the French survey, which, having commenced with Algiers and Morocco, will very probably be continued along Eastern Barbary and Tunis. (*a*)

"From the Strait of Gibraltar the western coast of Africa has been sufficiently surveyed and published as far as Cape Formoso, in the Bight of Benin; but as there is much legitimate traffic in the eastern part of that great Bight, as well as further to the southward, both it and many of the ports and anchorages on this side of the Cape of Good Hope require a more careful and connected examination.

"The charts of the whole of the Cape colony are exceedingly defective, and from thence to the Portuguese settlements of Delagoa we know scarcely anything. (*b*)

"From Delagoa to the Red Sea and the whole contour of Madagascar are sufficiently represented on our charts for the general purposes of navigation, though many further researches along the former coast might still be profitably made. (*c*)

"The Red Sea, part of the coast of Arabia, the Gulf of Persia, and many detached portions of the East Indies, have been already executed by the Company's officers; and no doubt it is intended that the coasts of Malabar and Coromandel shall soon be undertaken by the same hands. The long Malay Peninsula and the Strait of Malacca will require much time and skill to complete, and to combine with each other those parts that have been surveyed. (*d*)

"With the China Sea we are daily becoming better acquainted, but much is still to be done there; for probably not one of the multitude of rocks and shoals with which it is almost covered is put exactly in its right position; and while some are repeated two or three times, others have been omitted. (*e*)

"On the coast of China the charts are excellent from Canton round to the mouth of the great river Yang-tse-Kiang; but of the Yellow Sea we know very little, and still less of the Korea, Japan, and the coast of Tartary, and up to the confines of the Russian empire. (*f*)

"The southern passages into the China seas have never been examined with the care they deserve; and all that is known of what are called the eastern passages through the great Malay Archipelago are only the results of the casual observations and sketches made years ago by industrious seamen. (*g*)

"The islands and surrounding shores of the Arafura Sea, if better known, would offer many ports of refuge, and probably an increased opening to commercial enterprise.

"The Strait of Torres has been satisfactorily surveyed; but before it becomes the great highway for steam-vessels to and from Sydney, its approaches, and also its contiguous coasts of New Guinea, should be more intimately known. (*h*)

"The whole circuit of the great island of Australia has been well explored, and the general characteristics of its several shores are sufficiently known for all general purposes; but far more minute surveys of its immediate waters and maritime resources must precede their being inhabited, beginning with the eastern coast, along which the tide of colonization seems to be already creeping.

"The shores of Tasmania, in like manner, are but very roughly laid down, and even to this day there is no chart of the harbour and entrance to Hobart Town, its capital and principal seat of trade.

"A full survey of New Zealand has just been commenced, and will no doubt answer all the wants of both the settler and navigator. (*i*)

"In advancing to the eastward across the Pacific Ocean, there are many groups of islands with which our merchant-vessels have occasional traffic, or in which the whaling vessels refit, and which ought, therefore, to be more efficiently examined.

"On the opposite side of the Pacific some progress has been made in surveying the coast between the Russian territory and the Strait of Juan del Fuca; but with the long interval between the Oregon district and the entrance of the Gulf of California we are very superficially acquainted, and but little is known of the interior of that extensive Gulf. In the present state of those countries it does not appear necessary to push our survey into their inner waters; but there can be no doubt that the coasts of Mexico, Guatemala, and New Granada, which contain many valuable harbours and innumerable trading ports, ought to be minutely and connectedly surveyed. (*k*)

"From the Equator to Cape Horn, and from thence round to the river Plata, on the eastern side of America, all that is immediately wanted has been already achieved by the splendid survey of Captain (now Rear-Admiral) Robert Fitz Roy.

"Some parts of the great empire of Brazil we owe to the labours of Baron de Roussin and of other French officers; but there is much yet to be done on that coast between the Plata and the Amazon rivers, and again along Guayana and Venezuela up to the mouth of the Orinoco.

"The shores of the main land between Trinidad island and the Gulf of Mexico have been charted and published by the Admiralty; but many of the West India islands are still wanting to complete a wholesome knowledge of those seas. (*l*)

"The United States are carrying on an elaborate survey of their own coasts; and to the northward of them a part of the Bay of Fundy has been done by ourselves, as well as all the shores of Nova Scotia, Canada, and Newfoundland; and when these surveys are finished, we shall only want to complete the eastern coast of America, those of Labrador and of Hudson Bay, which, being in our possession, ought to appear in our charts with some degree of truth." (*m*)

As it is impossible here to open the question of the positions of the multitude of islands, of the Pacific especially, the apparent number of which has been so greatly increased by the errors of observation of navigators who have reported them, we can only recommend to the observer the propriety of fixing astronomically every island which he may fall in with, and to note any peculiarity by which it may be identified hereafter.

F. BEAUFORT.

SUPPLEMENT TO THE APPENDIX No. 10, BY THE HYDROGRAPHER, CAPTAIN WASHINGTON, R.N.

Ten years having elapsed since the above Memoranda were written, a few corrections become necessary, without, however, entering into details.

a. In the Mediterranean all the eastern islands are surveyed, with the exception of Scarpantho and Caxo and the surrounding islets and rocks. The coast of Syria, with the exception of the Gulf of Iskanderún, is still unsurveyed. That of Egypt, from El Arish westward to Alexandria, has been mapped and published. The northern part of the Dardanelles, the Bosphorus, the islets west of Sicily, as Maritimo, &c., and the Balearic Isles, still require to be surveyed.

b. In the Cape Colony the coast from Table Bay to Cape Agulhas, with Algoa Bay and Port Natal, have been surveyed. The rest of the coast, as far as Delagoa Bay, remains as before.

c. The islets and dangers off the north-west, north, and north-east of Madagascar, from the Comoro Isles to Diego Garcia, require to be examined.

d. In the Gulf of Persia the longitudes are very vague. The east and south coasts of Ceylon require examination, as well as the Andaman and Nicobar Islands, and from St. Matthew Isle, in 10° N. lat., to Prince of Wales Island. The coasts of Malabar and Coromandel are all but completed by the officers of the Indian navy. The Straits of Malacca and Singapore have also been surveyed, as well as those of Rhio and Durian. The east coast of Sumatra, from Malacca Strait to Sunda and Banca Straits, requires examination.

e. Java, and all the islands eastward, including Timor, with the Java Sea, Flores Sea, with the south coast of Borneo, Celebes, &c., and the islets and rocks in that region, have been partially examined by the Dutch, but no regular survey has been made. The west coast of Borneo, from Tanjong Api southwards to Sambar Point, has not been surveyed, nor have the islands and passages from the Strait of Gaspar to the Natunas. The west coast of Borneo, from Tanjong Api northwards, and Paláwan Island, have been surveyed, as well as the east coast of the Malay peninsula and the Gulf of Siam. Cochin China with some trifling exceptions, a part of the coast of Haïnan, and the whole of the Gulf of Tonking, may be considered as unknown.

f. Some detached portions of the coasts of Korea and Tartary, and of Japan, and some few of their harbours, have recently been examined: but of the coast of China northward of the Yang-tse-kiang, the gulfs of Pechili and Leaotong, we still know very little.

g. The Spaniards have surveyed a portion of the Philippine Islands, and the Dutch have made some partial surveys; otherwise the eastern passages remain as before.

h. The outer dangers off the east coast of Australia, in what is termed the Coral Sea, require careful examination.

i. The survey of New Zealand has been completed, and charts of the coast and plans of all the ports, with ample Sailing Directions, are published.

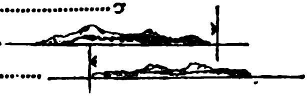
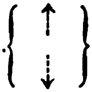
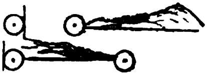
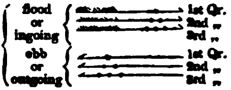
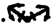
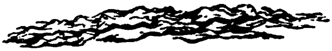
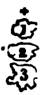
k. The Strait of Juan de Fuca, and the channels between Vancouver island and the mainland of British Columbia and Oregon, have been surveyed by England, and the coast thence to the Gulf of California by the United States.

l. The coast from the Gulf of Campeche to Texas has never been examined. Cuba, Jamaica, St. Domingo, and Puerto Rico have been partially examined, but are very far from being completely surveyed. The islands from Guadaloupe to Tobago, inclusive, with the exception of Martinique (which has been surveyed by France), require surveying.

m. The Bay of Fundy is all but completed, and the shores of Nova Scotia are in rapid progress. Newfoundland still remains only partially surveyed.

APPENDIX No. 11.

Useful Abbreviations in Surveying.

Two objects in a line (conjunction)	☌
Right tangent .... › .... *as*	
Left tangent .... › .... *as*	
Leading mark in a view or sketch	
Angle subtended	← 20° 30′ →
Sun's right limb	
Ditto left	
Ditto centre	⊖
Ditto upper	
Ditto lower	
No. of angle	∠•
Station	△
Windmill	
Church	
Direction of stream	 flood or ingoing ebb or outgoing 1st Qr. 2nd „ 3rd „ 1st Qr. 2nd „ 3rd „
Necessary to moor	
Whirl of tide	
Races and overfall	
Low-water standard	L. W. S.
Mean water level	M. W. L.
Rock which covers and uncovers	■
Rocks always under water	 + less than 1 fm. ....1 fm. ....2 „ ....3 „

ARTICLE III.

FIRST DIVISION, SECTION 3.

TIDES.

BY THE REV. DR. WHEWELL.

Directions for Tide Observations.

1. IN making tide observations, the main object is, in the first place, to refer the tides to the motions of the *moon*, by which they are, in most places, mainly governed.

For this purpose, the *time* and *height* of *high water* (and of *low water*) at each place must be obtained; and this *time* will have to be compared with the *time* of the moon's passage across the meridian of the place.

The latter time (the *time of the moon's transit*) may be known by the common table given in the Nautical Almanac, or in other books of the same kind.

2. The time of high water (and low water) may sometimes (when the sea is calm) be ascertained with sufficient accuracy by observing the surface of the sea, where it washes a vertical scale fixed in the open water, and divided into feet and inches. The moment when the water is highest (and lowest) must be observed by a watch or clock, well regulated or corrected for its error.

3. In general, the waves will make it difficult to observe the moment of the highest (and lowest) open water with much accuracy. The following methods may be used to make the observations more accurate :—An upright tube, open below and above, may be placed in the water, reaching above the high water and below the low water (or two tubes, one for high water and one for low water, if this

mode be more convenient). In this tube must be a float (a hollow box or ball, for example), which must carry an upright rod, or else must have attached to it a string which passes upwards over a pulley and is stretched by a weight; and the part of the rod or of the string which is outside the tube must carry an index, which shall mark on a vertical fixed scale the rise and fall of the float.

By making the tube close below, except one or more small openings, the motion of the waves will very little affect the float, and the true rise and fall of the surface may be observed with much accuracy.

4. It may happen that the moment of the highest or lowest water is difficult to determine, either with or without the tube, on account of the water, while near the highest or lowest, stopping or hanging still, without either rising or falling, or else rising and falling irregularly.

If there is a considerable time during which the water neither rises nor falls decidedly, note the moment when it ceases to rise, and the moment when it begins to fall, and take the time half way between these for the time of high water.

5. Another method is the following:—At certain intervals of time near the time of high water, for example, every ten minutes, or every five minutes, let the height of high water be observed, say for half an hour or an hour, and from the height so observed pick out the highest for the high water, and note the height and the time; and in like manner for low water.

6. But the following is a better mode of dealing with observations thus made every five or ten minutes. Let a number of parallel lines (*ordinates*) be drawn at intervals corresponding to the intervals of observations, and bounded by a line perpendicular to them on one side (the *abscissa*), and on these lines (the ordinates) let the observed heights of the surface be set off (from the abscissa), and let a line be drawn through the extremities (of the ordinates). This line, if it be tolerably regular, will give the time of high water; and if it be somewhat irregular, it can be smoothed

into a curve, and then the time and height of high water read off. And in like manner for low water.

Suppose, for example, that we have the following observations of the height of the water made every five minutes for an hour:—

Times of Observation		h. 0 m. 0	m. 5	m. 10	m. 15	m. 20	m. 25	m. 30	m. 35	m. 40	m. 45	m. 50	m. 55	m. 60
Heights observed	ft.	6	6	6	6	6	6	7	6	6	6	6	6	5
	in.	0	6	6	9	10	11	0	11	11	9	5	2	10

The selection of the greatest height (as in 5) would give high water at 0h. 30m.; but the general run of the height (6) would give the high water two or three minutes later, as appears by drawing the dotted curve in fig. 1.

This way of finding the exact time of high water (or low water) from observations made every five or every ten minutes, between some of which the highest water happens, is called "interpolating." See the article on Hydrography, Appendix No. 6, where we have the following observations, made at intervals of 10 minutes:—

	Time.		Height.	
	h.	m.	ft.	in.
P.M.	6	20	44	3
	6	30	45	2
	6	40	45	2
	6	50	44	8
	7	0	44	0

By interpolation from these observations, we find, for the exact moment of high water—

Time.		Height.	
h.	m.	ft.	in.
6	38	45	3

7. It is easy to draw such curves, if we have, ready prepared, *paper ruled* into small squares, the divisions in the horizontal line representing hours and minutes, and

the divisions in the vertical line representing feet and inches.

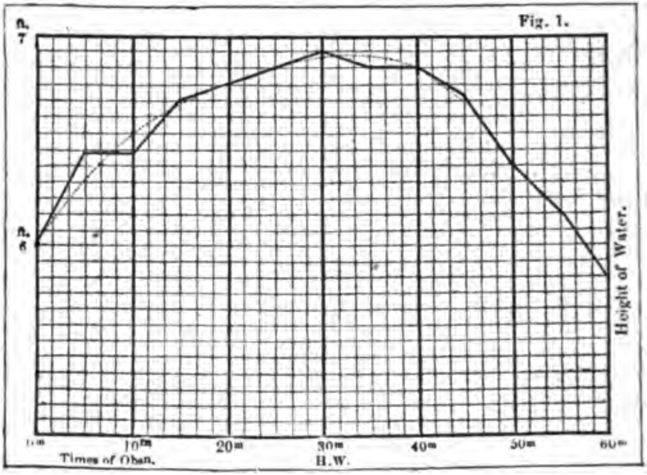


Fig. 1.

8. It is well to begin a series of tide observations at any place by observing the height of the water, during the *whole of the day and night*, every half-hour or every quarter of an hour. For if the rise and fall be very irregular, or have any features which make it differ much from the common rule, it will, by this means, be seen that the case is a peculiar one, and that peculiar methods must be used: but if there is nothing peculiar in the case, the common methods may be used.

For instance, if, instead of there being two tides in every (lunar) day, there be one only, or four (both which cases occur at several places), these peculiarities will be discovered by observations continued during the day and night, in the way just recommended. If there be a periodical rise and fall of the sea's surface not depending in any obvious way upon the moon, the periods of maximum and minimum should be carefully and exactly observed, in order to determine upon what the rise and fall do depend. This is the case in some parts of the Pacific, the rise and fall at those places being small.

9. If *the tides are tolerably regular*, it will not be necessary to observe, except for every five (or ten) minutes near the time of high water and low water—say, for an hour, so as to include the exact time near the middle of the hour. From these observations, by laying down the heights as ordinates, and drawing curves as directed in (6), the height and time of high water and of low water will be deduced.

10. It is desirable to compare the observations of the time of high water and low water with the time of the moon's transit (see 1) *while the observations are going on*; for if the tide follow this transit at very irregular intervals, the common modes of observation will probably be of no use, and the time and trouble employed in making them will be lost.

11. The time of high water at any place on the day of new or full moon is commonly called the *establishment* of the place; because, this being established, the time of high water on any other day may, in most cases, be known.

12. But if the tides are very irregular, this is not the case, and then the establishment of the place is of no use, or, rather, there is no proper establishment. And if the tides be regular, the establishment may be got from observations made *on other days*, just as well as from those made on the day of new or full moon. See Note A.

13. To compare the times of high water with the times of the moon's transit (see 10), we must take the moon's transit from the tables (see 1), and reckon how much the time of high water is *after* the time of the moon's transit, and put down these intervals, which are called the *lunitidal intervals*.*

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* It is not necessary, for the purposes considered in these directions, to calculate the time of the moon's transit *at the place of observation* by differences of days. It is sufficient to take the time of the moon's transit at Greenwich, and to *add* two minutes for every hour of *west* longitude of the place. For the moon (on the average) moves away

Suppose, for example, that we have obtained (as in 4, 5, or 6) the observations of high water contained in the following table: we add to them the other columns, containing the moon's transit and the lunitidal interval calculated therefrom. The alternate transits are interpolated midway between the others, which are given by the table in the Nautical Almanac. The A.M. transit which happens at 0h. 32m. on the 14th is given in that table as 12h. 32m. P.M. on the 13th, the hour of the table being reckoned from noon in the Nautical Almanac.

1847. Jan.	Times of H.W.	Times of Moon's Transit.	Lunitidal Interval.	1847. Jan.	Times of H.W.	Times of Moon's Transit.	Lunitidal Interval.
	h. m.	h. m.	h. m.		h. m.	h. m.	h. m.
11 A.M.		[10 33]		16 A.M.	3 54	2 6	1 48
P.M.	1 7	10 57	2 34	P.M.	4 9	[2 29]	1 40
12 A.M.	1 29	[11 21]	2 32	17 A.M.	4 26	2 52	1 34
P.M.	1 51	11 45	2 30	P.M.	4 43	[3 15]	1 28
13 A.M.	2 11		2 26	18 A.M.	5 3	3 39	1 24
P.M.	2 29	[0 9]	2 20	P.M.	5 23	[4 3]	1 20
14 A.M.	2 48	0 32	2 16	19 A.M.	5 46	4 27	1 19
P.M.	3 3	[0 55]	2 8	P.M.	6 9	[4 51]	1 18
15 A.M.	3 21	1 19	2 2	20 A.M.	6 34	5 16	1 18
P.M.	3 36	[1 42]	1 54	P.M.	7 1	[5 41]	1 20

In this table, by subtracting [10h. 33m.] the time of the [interpolated] moon's transit from 1h. 7m., or rather from 13h. 7m., the observed time of high water, we get 2h. 24m., the lunitidal interval; and so on for the rest.

14. To see whether the lunitidal intervals follow the regular law, the best way is to put them into a curve, setting off the lunitidal interval belonging to each tide as an ordinate, as in fig. 2.* If the curve drawn through the extremity of the ordinates be tolerably regular, the tides may be presumed to be so.

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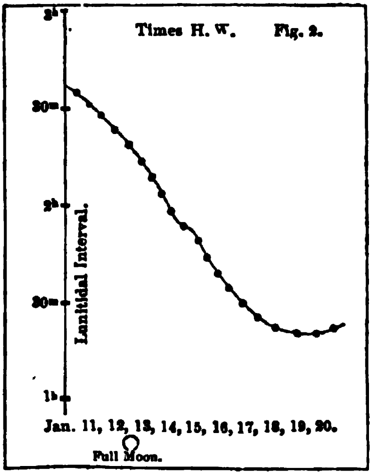
from the sun so that her distance from the sun is increased 48 minutes in time for every 24 hours, and therefore the transit of the moon is later at every other place by two minutes for every hour.

* In actual practice it will be better to draw the figures on a larger scale than those here given.

Fig. 2 represents the lunitidal intervals given in (13).



15. In the observations given in (13) we may see how loose a term the "*establishment*" is. The 13th is the day of full moon, for in the course of that day the moon is 12 hours from the sun, as appears by the times of her transit. The time of high water on the 13th is—A.M., 2h. 11m.; P.M., 2h. 29m.; and either of these might, in the common use of the term, be called "the establishment."

16. If the lunitidal intervals be set off for a fortnight or more, the curve (14) will descend and ascend alternately every fortnight, as in fig. 3.

This curve is the curve of the *semi-mensual inequality*; and when this curve has been determined by observations at any place, the hour of high water at any time at that place may be predicted.

17. But the curve will be better determined if, instead of taking for the abscissa the day of the month, as in fig. 2,

we take for the abscissa the time of the moon's transit, as in fig. 3.*

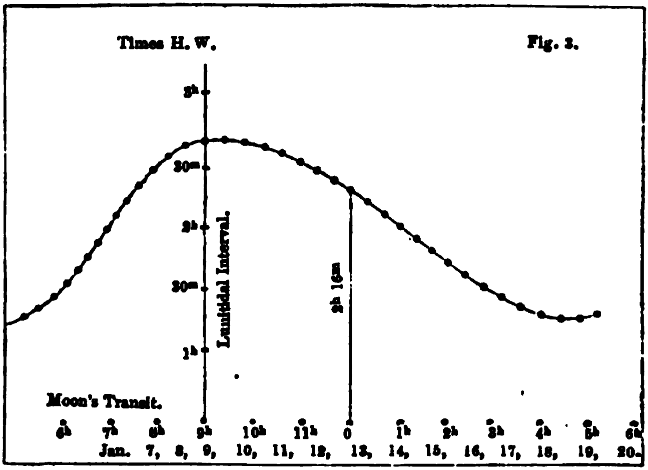


Fig. 3.

In this case *the establishment* is the ordinate of this curve which corresponds to the time of moon's transit 0h. or 12h. In the figure it is 2h. 16m.

The mode of calculating the hour of high water on any day, when the establishment of the place is known, is given in Note A.

The establishment of the place may be known by observations made at any age of the moon, as well as by observations at new and full moon, by the same kind of calculation.

18. In order to determine the *law of the heights of high water* during the period from springs to neaps, we must set off the *heights* of high water as ordinates, and draw a curve through the extremities. This curve also will ascend and

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* Since the moon's transit is about 48 minutes later every day, there will be along the abscissa five days of the month for every four hours of moon's transit.

descend every fortnight (ascending at spring tides and descending at neap tides).

The heights may be set off as ordinates, taking for the abscissæ equal intervals to represent successive half-days, as in (16).

But the curve will be better determined if we take for the abscissæ the hour of the moon's transit, as in (17).

19. The *maximum* or greatest ordinate of this curve of heights (that is, the spring-tide height) follows the day of new and the day of full moon, by one, two, or three days; and as the new or full moon is supposed to produce the spring tide, this interval of one, two, or three days is called *the age of the tide.*

20. If the heights be set off from an abscissa which is the hour of the moon's transit (see 18), the distance of the maximum ordinate from the hour of transit, 0h. or 12h. (which are the same thing), will give the *age of the tide* more exactly than the process in (19).

21. The lunitidal intervals and heights of *low water* may be laid down in curves in the same manner as those of high water.

22. The curve of the semi-mensual inequality of times and heights should be determined, when opportunity allows, for several weeks or months in succession: for from such observations we can obtain other scientific results (the effect of the sun, the effect of the moon's parallax, and the like).

23. Besides the changes which are produced from day to day by the semi-mensual inequality of times and heights, there are at many places other considerable changes produced between the two tides of the same day by the *diurnal inequality.*

For example, there are many cases in which the height of high water is alternately lower and higher in successive tides.

24. In this case, if we set off the successive heights of high water as ordinates at equal intervals, and draw a

line through their extremities (as directed in 18), this line will have a zigzag form, as in fig. 4.

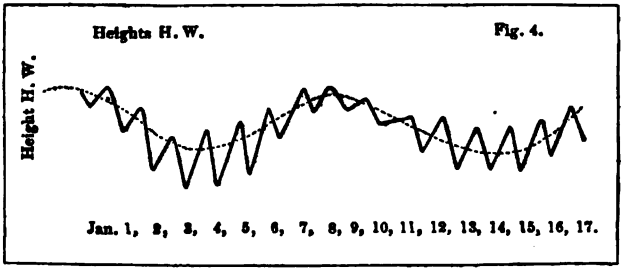

Fig. 4.

The width of the zigzag increases from nothing to a maximum, and then diminishes to nothing again, generally in the course of a fortnight; and so on perpetually.

25. In consequence of the diurnal inequality, it sometimes happens that the afternoon tides are higher than the forenoon tides, or the reverse, for many weeks together. And hence it has sometimes been stated as a Rule at such places that the afternoon tides are always the highest, or the reverse. But this is not the Rule. If the afternoon tides are the highest at one time of the year, they are the lowest at another.

The Rule of the diurnal inequality depends on the moon's declination, and will be given in Note B.

26. There is often a diurnal inequality of the height of low water, and at some places it is greater than the diurnal inequality of high water (as at Sincapore, and at Port Essington in Australia).

27. Also there is often a diurnal inequality in the times. When this is the case, if we set off the lunitidal intervals as ordinates (see 14), the line drawn through their extremities will have a zigzag form, like that of the heights in fig. 4.

28. When this is the case, we cannot determine *the esta-*

blishment (see 17) without making allowance for the diurnal inequality.

We make allowance for the diurnal inequality by drawing a curve, cutting off from the zigzags equal portions above and below. (See fig. 4). This *mean line* will be of a wavy form in consequence of the semi-mensual inequality; and the ordinate corresponding to the new or full moon, or to the hour 0 or 12 of moon's transit, will give the establishment.

But if we apply this establishment to predict the time of tide on any day, we must also apply the diurnal inequality predicted according to its rule. (See 25, and Note B.)

29. The diurnal inequality sometimes becomes so large that there is *only one tide in 24 hours* (and thén we have *single day tides*). But this does not generally happen through a whole lunation; it happens only for a few days in each semi-lunation; and at other times there are two tides as usual. Cases of one tide in 24 hours should be particularly observed, making the observations every half-hour, or, if possible, oftener—say every 5 minutes.

30. In some places the tide rises and falls *four times* in the 24 hours. The cases where this occurs are to be particularly observed.

They may be observed, as in (29), by making observations every half-hour, 10 minutes, or 5 minutes.

These may be called *double half-day tides.*

31. Where double half-day tides exist, they do not commonly extend over any considerable length of coast. If there be time and opportunity, it will be well to examine, by observation, how far they do extend. But if the object be to determine the laws of the tides in a larger area, it is better to make the observations out of the region of these anomalies.

32. It is well to observe the *direction* of the stream of flood and of ebb, and the *time* at which the stream turns.

We must take care not to confound the time of the *turn of the tide-stream* with the time of high water. Mistakes and errors have often been produced in tide observations by supposing that the turn of the tide-stream is the time of high water. But this is not so. The turn of the stream generally takes place at a different time from high water, except at the head of a bay or creek. The stream of flood commonly runs for some time, often for hours, after the time of high water. In the same way, the stream of ebb runs for some time after low water.

33. The time at which the stream turns is often different at different distances from the shore; but the time of high water is not necessarily different at these points. The time of *slack water* is not wanted for a theory of tides, though its knowledge is otherwise of considerable importance to the seaman.

With regard to the streams of flow and ebb, they are often not merely two streams in opposite directions at different times of the tide; they generally turn successively into several directions, so as to go quite round the compass in one complete tide, either in the direction N., E., S., W. (with the sun), or N., W., S., E. (against the sun). It is desirable to note which of these ways the tide-stream goes round, as this fact may help to determine which side the tide-wave comes from.

34. One important object to be answered by means of tide observations is to trace the progress of the tide from one place to another.

This may be done in some measure by determining the *establishments* of a series of places in the region which we have to consider. For these establishments, reduced to Greenwich time by allowing for the longitude, give the time at which the tide is at each place, and hence its progress.

35. The progress of the tide may be conceived as the progress of a very wide *wave* which brings the high water to each place in succession.

But the motion of this *tide*-wave is not that motion of the water which makes the stream of flood. Nor does the motion of the wave coincide with any motion of the parts of the water. The tide-wave may be going one way when the water is going another, as happens in some rivers when the tide is travelling upwards in them.

36. The *establishment*, which is wanted in order to determine one progress of the tide-wave (see 34 and 35), may be known from observations made at any age of the moon, as well as at new or full moon. (See 17 and Note A.)

37. In tracing the progress of the tide-wave, instead of using the *vulgar establishment* hitherto spoken of, it is better to use the *mean establishment*, namely, the mean of all the lunitidal intervals.

For the vulgar establishment is affected by the age of the tide (20), which the mean establishment is not.

The mean establishment is (say) 10m., 20m., 30m., or 40m. less than the vulgar establishment, according to the age of the tide. (See Note A.)

38. When the tides are regular, good observations, made for a few days or a week at each place, may give the establishment (either vulgar or mean) with sufficient exactness to determine the progress of the tide-wave.

39. But the progress of the tide-wave may be much better determined by means of *simultaneous observations*, namely, observations made at different places on the same days for a few days or a week.

For such a purpose persons must be posted at different points of the shore or shores where the motion of the tide-wave is to be traced; say 10, or 20, or 40, or 80 miles from each other, as may be convenient. They must observe the tides at these places *on the same days*, morning and evening, by the methods already described. The times of high water at the different places on each half-day, being compared, will give the progress of the tide-wave.

40. In order to trace the progress of the tide-wave still more widely, the observers described in (39), after having made the observations there spoken of, may be removed to new positions of the same kind, and thus trace the tide farther.

When this course is adopted, it will be well to have one (or more) fixed or standard station, at which tide observations are constantly made; and the observations made at any time at any other place may be compared with those made at the standard station.

41. The tides which take place far up deep bays, sounds, and rivers, are *later* than the tides at the entrance of such inlets, but they are not more irregular; on the contrary, the tides in such situations are often remarkably *regular*.

42. The progress of the tide-wave up inlets may be determined by the method described in (39).

43. The tide in its progress up inlets and rivers is often much magnified and modified by local circumstances.

Sometimes it is magnified so that the wave which brings the tide at one period of its rise advances with an abrupt front of broken water. This is called a *bore* (as in the Severn, the Garonne, the Amazon).

Sometimes the tide is divided into two half-day tides in its progress up a river (as in the Forth in Scotland).

In all cases, after a certain point, the tide dies away in ascending a river.

44. The tide observations made at any place, when the times and heights of high water (and of low water) have been deduced in the way directed in 2, 3, 4, 5, 6, may be entered in a table of which the form will be given (Note C), and must then be sent to the Hydrographer's Office in the Admiralty.

45. It is to be remarked that, though there is generally an A.M. and a P.M. tide, there is one day in every half-lunation on which there is only one tide.

(Because the interval of the two tides is, on the average, about 12h. 24m.; so that if there be a tide at 11h. 50m. A.M., there will be no other tide till 12h. 14m. P.M., that is, 0h. 14m. A.M. of the next day.)

46. *Self-registering tide-machines* are used in several places, and may be constructed at no great expense. They are constructed so as to work with a tube and float, as described in (3). These machines give the whole course of

rise and fall of the tide; and record several successive tides on the same paper.*

47. The wind often produces a considerable effect upon the tides, especially upon the height, and should be noted, although it is difficult to give any general rule for the effect.

48. The surface of the sea rises and falls as the barometer falls and rises: namely, about 1 inch for every $\frac{1}{10}$ inch of mercury. This may be applied as a correction when very exact observations are made.†

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* Of tide-gauges, one of the most elaborate and successful is that invented by Mr. Bunt, and described in the 'Phil. Trans.' for 1838. It is also described by the Astronomer Royal in the article 'Tides and Waves' of the 'Encyclopædia Metropolitana.' Tide-gauges are constructed by Mr. Newman, of Regent-street, London, at an expense of about 30*l.*

† Naval officers will be in a better condition to judge of the value of carefully made observations in bringing to perfection the theory of the tides, after reading the practical part of the invaluable article by the Astronomer Royal in the 'Ency. Metrop.' before referred to. References are there made to the researches of Dr. Whewell and Sir John Lubbock, printed in the 'Phil. Trans.' Sir John Lubbock's researches are contained chiefly in the 'Phil. Trans.' for 1831 and 1833, while those of Dr. Whewell, consisting of fourteen distinct memoirs, extend from the year 1833 to 1850. In the 'Phil. Trans.' for 1845 is a very valuable paper, by the Astronomer Royal, on the 'Laws of the Tides on the Coasts of Ireland;' and in the volumes for 1848 and 1851 are two papers by the late Admiral Beechey on the Tides in the Irish Sea and the North Sea and English Channel respectively. Some valuable observations on the Tides in the North Sea, by the late lamented Captain Hewett, will be found in the Report of the eleventh meeting of the British Association.—(B. M.)

APPENDIX.

NOTE (A.)

NOTE TO 12, 17, 36, AND 37.

To find the Hour of High Water on any day, at any place, when the Establishment of the place is known.

THE rule is different (as to amount) according to the *tidal force* of the sun; for though the tidal force of the sun in theory is the same at all places, it is found by observation to be different at different places.

This difference appears in the different ratio of the rise of spring-tides to the rise of neap-tides (the semimensual inequality of heights). In general the rise of spring-tide above mean water is about double that of neap-tide, which gives the solar tide *one-third* of the lunar tide. But in some cases the spring-tide exceeds the neap-tide only by one-third, which gives the solar tide only *one-seventh* of the lunar tide.

Also the difference of the greatest and least lunitidal intervals (that is, the semimensual inequality of times: see 13 and 16) shows the difference of the solar tidal force at different places. The difference of the greatest and least intervals is 1 h. 28 m. at London and Liverpool, but at Plymouth it is 1 h. 36 m., and at Portsmouth 1 h. 21 m. On the coast of North America it is generally less than 1 h. 20 m., while at some places on the coasts of France and Ireland it is above 2 h.

We may take 1 h. 28 m. as the mean value of this difference, which agrees with the supposition that the solar tide is about one-third the lunar tide.

In finding the hour of high water on any day when the *vulgar* establishment is known, the rule will also be different according to the age of the tide. We shall give the rule when the tide is a day and a quarter old, and also when the tide is two days and a half old. In general, the tides will be between these limits.

(1.) *Tide a day and a quarter old.* Minutes to be added to or subtracted from the establishments, according to the hour of the moon's transit on the half-day in question :—

Hour of the Moon's Transit after Sun. .	h. 0	h. 1	h. 2	h. 3	h. 4	h. 5	h. 6	h. 7	h. 8	h. 9	h. 10	h. 11
Correction of the vulgar Establishment to find the Lunitidal Interval	m. 0	m. −16	m. −32	m. −47	m. −57	m. −60	m. −47	m. −16	m. +15	m. +28	m. +25	m. +15

For example—if the establishment be 2 h. 27 m., at what hour will the high water come after a moon's transit which takes place at 4 h. A.M.? The minutes to be added to 2 h. 27 m. for 4 h. transit are, by the table, − 57 m., that is, 57 m. to be subtracted; therefore the high water will be at 1 h. 30 m. after the moon's transit, that is, at 5 h. 30 m.

(2.) *Tide two days and a half old* :—

Hour of Moon's Transit	h. 0	h. 1	h. 2	h. 3	h. 4	h. 5	h. 6	h. 7	h. 8	h. 9	h. 10	h. 11
Correction of the Establishment	m. 0	m. −15	m. −31	m. −47	m. −62	m. −72	m. −75	m. −62	m. −31	m. 0	m. +13	m. +10

This table is to be used in the same way as the other.

Hence we see that the age of the tide most affects the lunitidal interval when the time of moon's transit is between 7 and 8 hours.*

The mean lunitidal interval, or *mean establishment*, is 16 minutes less than the former, and 31 minutes less than the latter (vulgar) establishment supposed in the above tables. (See 37.)

If the tides are observed for a semilunation, or any complete number of semilunations, the mean lunitidal interval, or mean establishment (see 37), will be found by taking the mean of all the lunitidal intervals observed.

The lunitidal interval *corresponding to* any given distance of the moon from the sun may be found by the following table. But the tide corresponding to the given distance may not really *occur* till one, two, or three days later, according to the age of the tide.

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* Hence it is desirable to make tide observations in the first and fourth quarters of the moon, rather than in the second and third quarters.

(3.) Correction of *mean* establishment.

Hour of Moon's Transit (1, 2, 3 days preceding)	h. 0	h. 1	h. 2	h. 3	h. 4	h. 5	h. 6	h. 7	h. 8	h. 9	h. 10	h. 11
Corresponding Correction of Mean Lunitidal Interval. . . .	m. 0	m. −16	m. −31	m. −41	m. −44	m. −31	m. 0	m. +31	m. +44	m. +41	m. +31	m. +16

This table may be used when we know the age of the tide. Thus let the age of the tide be a day and a quarter, and the mean lunitidal interval 2 h. 11 m.; let the moon's transit take place at 4 h.; then at the *birth of the tide*, a day and a quarter earlier, the transit took place at 3 h.; therefore the correction of the lunitidal interval is, by the table, − 41 m., and the interval so corrected is 1 h. 30 m., which, added to 4 h., the time of moon's transit, gives 5 h. 30 m. as the time of high water.

To find the Establishment at any place when the Hour of High Water on a given day is observed.

On the given day the time of moon's transit is known, and hence the lunitidal interval; and, by the above tables, the correction by which this differs from the establishment is known.

Thus, if high water occur at 5 o'clock when the time of moon's transit is 3 h., the lunitidal interval is 2 h.; and the correction (if the first table be applicable) is − 47 m.; hence the establishment is 2 h. 47 m.

NOTE (B).

NOTE TO 25 AND 28.

The Rule of the Diurnal Inequality.

THE Diurnal Inequality depends upon the moon's declination, as has been said already. It increases from 0 up to its maximum, and decreases to 0 again, as the declination does so; following these changes at an interval of one, two, or three days, according to the age of the tide. The rule is expressed in this way:—

For *north* declination of moon,
    Add to the tide following moon's *south* transit;
    Subtract from the tide following moon's *north* transit.

For *south* declination of moon,
Subtract from the tide following moon's *south* transit;
Add to the tide following moon's *north* transit.

The south transit is the superior transit in the northern hemisphere, and the north transit the inferior. The contrary is the case in the southern hemisphere.

NOTE (O).

FORM FOR TIDE OBSERVATIONS.

Tides observed at , *Lat.* , *Long.* . *By*

Mode of observation . . . . . { Fixed scale in open water? / Tube with float? / Self-registering gauge?

Mode of deducing H.W. and L.W. { Mere looking? / Ordinates every 5 m. near max.?

18 .		High Water.		Low Water.		Wind.	Barom.	Moon's* Transit.	Lunitidal* Interval. H. W.
Month.	Day.	Height.	Time.	Height.	Time.				
	1 A.M.								
	P.M.								
	2 A.M.								
	P.M.								
	3 A.M.								
	P.M.								

* These columns to be filled at leisure (see 13, 41).

ADDITIONAL REMARKS.

The general progress of the tide-wave (35) along even the most frequented shores is still imperfectly known; and about the connexion of the tides over the general areas of large oceans we are as yet entirely in the dark; there is therefore an ample field of important and useful discovery in this subject, even by means of brief and scattered series of observations; still more is this the case if simultaneous or connected observations can be made, such as are described in 39 and 40.

The main general features of the progress of the tides, as hitherto ascertained, are the following:—

The tide-wave which brings the tides to the coasts of Europe comes from the Atlantic, and brings high water to the western coast of Spain and Portugal about 2 hours after the moon's transit; to the western coast of France about 3 hours; to the western coast of Ireland and to the Land's End about 4 hours. The tide-wave then runs along the south coast of England, and the north coast of France, to the Straits of Dover, which it reaches about 11 hours after the moon's transit. It runs also along the west coast of Ireland and Scotland, and reaches the Orkneys about 9 hours after the moon's transit. From thence it enters the German Ocean, and runs along the east coast of Britain, so as to reach Peterhead about 12 hours after the moon's transit, and Harwich in about 12 hours more, where it meets the tide-wave which had come through the Straits of Dover derived from the same Atlantic wave about 12 hours earlier. The tides of the German Ocean are produced by the mixture of these two tide-waves, and hence follow complicated laws: as for the same reason do those of the Irish Channel.

The tide-wave which brings the tides to the eastern coast of North America appears to reach the southern parts about 7 hours, and the northern parts of the United States about 11 hours, after the moon's transit; but its course has not yet been distinctly traced.

How the tides on the eastern and on the western shores of the Atlantic are connected has not yet been clearly shown. It is difficult to explain the tides of the Atlantic Islands (Madeira, Teneriffe, &c.) by any simple form of a tide-wave.

It is remarkable that the European tide-wave, though following the moon's transit at a definite interval (nearly), moves (at first) in a direction opposite to the moon—namely, from west to east.

If we go to the Pacific, we find the same phenomenon. The tides on the western shore of South America, near Cape Horn, also move from west to east. They are simultaneous with the moon's transit at Chiloe; 1 hour after at Cape Pillar; and at Cape Horn it is 3½ hours later than this.

Along a large portion of the west coast of the Pacific, it seems difficult to say whether the tide-wave travels northward or southward. From the Isthmus of Panamá, however, it appears plainly to travel to the northward, occupying about 12 hours to run from Realejo to Nootka Sound.

In the western parts of the Pacific the tide-wave runs to the westward, as we learn by its progress along the coasts of New Zealand and Australia, where the movement is better known than on any coasts out of Europe. It visits New Zealand about 6 hours, and Australia about 10 hours, after the moon's transit *at Greenwich*.

In the central parts of the Pacific the tides are small and anomalous (for they do not clearly depend on the moon), and hence it is still more difficult to connect the *littoral* tides than in the Atlantic Ocean.

The outer regions of the Pacific, broken by large islands, and the Indian Ocean, have tides, of which the laws of progress are more complex, and have not yet been disentangled.

The Diurnal Inequality (23, &c.) adds to the complexity of the tides. This inequality appears very conspicuously in the tides on the west coasts of Europe and the east coasts of North America; but its maximum in those two regions does not appear to be simultaneous. It is very large in the Indian Ocean and on the coast of Australia, having different phenomena at different places, as noted in 26 and 27.

The movement of the tide along the surface of the ocean may be in some measure represented in the following manner: Draw lines through all the places where it is high water at the same time; that is, one line (generally it will be a curved line) through all the places where it is high water at *One* o'clock; another line through all the places where it is high water at *Two* o'clock; and so on. These lines, being the lines at which the tide is contemporaneous, are called *cotidal* lines. They represent the form of the *tide-wave* which carries the tide from one point of the shore to another.

Such cotidal lines have been drawn (in the Phil. Trans. for 1833 and 1836, by Dr. Whewell) for those shores on which the tides are best known, and especially for the *coasts* of Europe.

But it appears that we cannot, by means of such cotidal lines, express the movement of the tides in oceanic spaces. The cotidal lines can only be drawn in the neighbourhood of *coasts*.—(Phil. Trans., 1848, Part I.)

⁂ The best way to disentangle the phenomena of the tides when we are observing them at any place is to refer the time of high water and low water to the time of moon's transit; and to do this *at once*, while the series of observations is going on. For want of following this rule, it has very often happened that long series of tide observations have been made, which could not be turned to any use afterwards; and in almost every case the usefulness of such observations is by this method much increased, and the labour much diminished.

ARTICLE IV.

SECOND DIVISION, SECTION 1.

TERRESTRIAL MAGNETISM.

BY MAJOR-GENERAL EDWARD SABINE.

[*The Article on Terrestrial Magnetism has been re-written for the present Edition. The description and use of the Unifilar Magnetometer in Appendix No.* 1, *and an addition to Appendix No.* 3, *have been contributed by Mr. Welsh, of the Kew Observatory.*—E. S.]

1. THE magnetic observations which have been made and are at present making by naval officers have for their object the determination of the *amount* and *direction* of the *Earth's magnetic force* in different parts of the globe.

2. The amount of the magnetic force at any point of the Earth's surface may either be measured in *absolute* value, or its *ratio* may be ascertained to the value of the force at another station where its absolute measure is already known. No means have yet been devised for measuring *absolute* values at sea; consequently, all determinations of the magnetic force on board ships are necessarily of the *relative* class; these give the ratio, or proportion, which the force at the geographical position in which the ship is at the time when an observation is made, bears to its value at some land station which is included in the same series of relative observations, but where an absolute determination has also been made. Ships are therefore supplied with instruments for both absolute and relative determinations; the latter to be used chiefly at sea, but also on land at times when the ship is in harbour; the former to be used exclusively on land.

Absolute *Measurement of the Magnetic Force.*

3. No satisfactory method has yet been generally practised for the direct absolute measurement in one operation of the *whole* magnetic force of the Earth (called the "total force") at any particular point of its surface. But that portion of the force which acts in a direction parallel to the surface of the Earth (called the "horizontal component") may be measured with considerable accuracy by a process, of which the following brief description may suffice to give a general idea. If a magnet be suspended horizontally by a few fibres of silk, and made to vibrate in the horizontal plane on either side of its position of rest, the square of the number of vibrations in a given time is a measure of the horizontal component of the magnetic force of the Earth. But this measure is dependent on the individual properties of the magnet employed; and these properties influence the time of vibration; first, by the greater or less magnetic force which the magnet itself possesses; and, second, by the effects of the form and weight of the magnet. The latter effect, that of the form and weight of the magnet, may be eliminated when the moment of its inertia is learnt; and this may either be calculated by known rules, or may be ascertained experimentally by vibrating the magnet 1° in its usual state, and 2° with its moment of inertia increased by a known amount. The influence of the magnetic force possessed by the magnet may also be eliminated by ascertaining its magnetic moment. This is accomplished by using it to deflect a second magnet similarly suspended in another apparatus. The deflecting magnet is placed at one or more well-measured distances from the centre of the suspended magnet, and perpendicular to it. The deflections thus produced (*i.e.* the angular differences in the positions of rest of the suspended magnet, 1° when influenced solely by the Earth's magnetism, and 2° when in equilibrium between the Earth's magnetism and that of the deflecting magnet at the distances employed) furnish the *ratio* of the forces exerted respectively by the Earth's force

and that of the magnet; and as the *product* of the same two forces is given by the vibrations of the deflecting magnet when suspended as in the experiments first described, the values of either force may be separately ascertained. The influence of the magnetism of the magnet, and of its form and weight, being thus eliminated, a measure is finally obtained of the force of the Earth's magnetism, independent of the individual properties of the magnet employed in the determination.

4. The numerical expression by which the measure of the Earth's force thus obtained is denoted, depends on the units of time, of space, and of mass employed in the measurements and calculation. In conformity with the Instructions published under the authority of the Royal Society, a second of time, a foot of space, and a grain of mass, are the units so employed. The horizontal component of the Earth's magnetic force has been found, by the observations hitherto made, to vary at different points of the Earth's surface from 0 to about 8·4 of the scale founded on the units which have been specified.

5. Wherever the horizontal component of the force has been ascertained in absolute measure, there also, if the magnetic direction be known, the "total force" in absolute measure is determined; since it consists of the horizontal component multiplied by the secant of the angle which the magnetic direction makes with the horizon. As ships are supplied with instruments by which this angle, called the *dip* or *inclination* of the needle, is measured, the observations on land, when the ship is in harbour, give determinations of the *total force*, which serve as *base determinations*, to which are referred the *relative* results obtained at sea in the passage from one station of well-assured *absolute* determination to another;—a practice corresponding to that which prevails in determinations of longitude, where stations of well-assured longitude are taken as *base stations*, to which intermediate observations are referred. The total force of the Earth's magnetism, expressed in the scale in which the British units already referred to are employed, has been

found to vary at different points of the Earth's surface where observations have hitherto been made, from about 6·4 to 15·8. Before the practice of determining absolute values was adopted, various relative scales were employed, not always commensurable with each other. The one most generally used (and which still continues to be frequently referred to) was founded on the time of vibration of a magnet observed by M. de Humboldt about the commencement of the present century, at a station in South America where the direction of the dipping-needle was horizontal; a condition which was for some time erroneously supposed to be an indication of the minimum of magnetic force at the Earth's surface. From a comparison of the times of vibration of M. de Humboldt's magnet in South America and in Paris, the ratio of the magnetic force at Paris to what was supposed to be its minimum was inferred; and from the result so obtained, combined with a similar comparison made by myself between Paris and London in 1827 with several magnets, the ratio of the force in London to that of M. de Humboldt's original station in South America has been inferred to be 1·372 to 1·000. This is the origin of the number 1·372, which has been generally employed by British observers, not furnished with the means of making absolute determinations, to express the value of the magnetic force at their base station, viz. London. The essential disadvantage, however, under which any relative scale of the nature referred to labours, is, that the magnetic force of the Earth has been found to be subject to *secular variations*, so that at no one spot on the surface of the globe can the intensity be assumed to remain constant, and thus to afford a secure unvarying basis for such a scale; whereas, by *absolute* measurements, we are not only enabled to compare numerically with one another the results of experiments made in the most distant parts of the globe, with apparatus not previously compared, but we also furnish the means of comparing hereafter the intensity of the force which exists at the present epoch, with that which may be found at future periods. It is probable, from these and other considerations, that the employment of merely relative scales will shortly be entirely superseded by the general adoption of a scale in which the value of the force is expressed in terms of a fixed and unchanging unit.

6. The instrument with which the absolute value of the horizontal component of the force is measured is called the Unifilar Magnetometer; its description, and that of the process by which results are obtained with it, are given in Appendix No. 1. A tolerably practised observer will complete the process by which a measure of the absolute horizontal force is obtained in about two hours, including the time required for setting up and adjusting the instrument. It is desirable that there should be at least five or six repetitions at places which are to serve as base stations. There are certain constants (such as the moment of inertia of the magnet and stirrup in which it rests,—the change which the magnetic moment of the magnet undergoes from an alteration of one degree of temperature,—and the coefficient in the correction required for an increase of force which the magnet, in certain positions in which it may be used, may receive by induction from the earth) which have to be determined for each magnet once for all, and require for their determination apparatus which is not afterwards needed: these constants have hitherto been usually determined at Woolwich or at Kew before the instrument is put into the hands of the officer who is to use it elsewhere.

Relative *Measurements of the Magnetic Force.*

7. These are the observations which are made *at sea*, to determine the ratio of the total force, in the geographical position of the ship at the time when the observation is made, to its value at some base station where the instrument has been landed and used in observations precisely similar to those made on board ship. The instrument is the well-known apparatus devised by Mr. Fox, which has contributed more to a knowledge of the geographical distribu-

tion of terrestrial magnetism than any other recent invention. The following brief description may serve to give a general idea of the apparatus and of the mode of obtaining results with it; more full directions for its use being given in Appendix No. 3. It consists of a dipping-needle and graduated circle, differing little from the accustomed form of an Inclinometer, except that the needle is supported by the ends of the axle, which terminate in cylinders of small diameter working in jewelled holes. A small grooved wheel is carried on the axle, and receives a thread of unspun silk, furnished at each extremity with hooks to which small weights may be attached, for the purpose of deflecting the needle from its position of rest in the magnetic direction, and causing it to take up a new position in which it is in equilibrium between the opposing forces of the Earth's magnetism and of the deflecting weight. The weight being constant, and the magnetism of the needle assumed to be so, the intensity of the Earth's magnetic force in different localities is inversely as the sines of the angles of deflection. For greater accuracy, several constant weights are employed on each occasion; and each weight is successively attached to each of the two hooks, a mean being taken of the deflections on either side of the position of rest. The apparatus when used at sea is placed on a gimball table, by which the motion of the vessel is greatly counteracted; and when the weather does not permit the manipulation of the weights, deflecting magnets are substituted, the operation of which may be understood from the detailed instructions in Appendix No. 3. With the gimball table as recently constructed, it is found that but very few days occur in which the angles of deflection, either with weights or deflectors, cannot be satisfactorily ascertained by a careful observer. It is necessary that a spot should be selected for the observations to be made on board ship, which should have as little iron as possible within 5 or 6 feet of it; and that the instrument should always be used in the spot so selected. It must be carefully borne in mind, that the inverse proportionality of the sines of the angles of deflection to the variations of the Earth's magnetism, is only true when the magnetism of the needle has not varied; and although the needles made by Falmouth artists, under Mr. Fox's own superintendence, have generally proved most remarkable in preserving their magnetism unchanged for years and in all climates, it is desirable that reference to a base station should be made as often and with as short intervals as may be convenient; and evidence of this nature must always be furnished that the magnetism of the needle has not changed in a certain interval, before the relative determinations made during that interval can be relied on. The more frequently references are made to base stations at which the value of the magnetic force is known, the less danger exists that the labour bestowed on observations at sea will prove unproductive; and the more stations are multiplied which afford opportunities of such reference, the greater become the facilities for accurate determinations at sea.

Direction of the Earth's Magnetic Force.

8. The direction of the Earth's magnetic force undergoes every possible variation at different parts of the Earth's surface. For the purpose of determining and representing this direction, it has long been customary to refer it to two planes—the horizontal and the vertical—and to take the geographical north as the zero of the horizontal plane, and the horizontal line as the zero of the vertical plane. The *declination* (or *variation*, as it is more usually called by naval men) is the angular difference, measured on the horizontal plane, between the direction of the north end of a magnet or needle and the geographical north point;—and the *inclination* (or *dip*, as it is frequently called) is the angular difference, measured on the vertical plane, between the direction of the same north end of a magnet or needle and the horizontal zero point. (The north end of a magnet here spoken of is that end which in Europe points towards the north, and dips below the horizon.) The declination is called West, if the direction of the north end of

the magnet or needle is to the west of the geographical north, and is reckoned from 0° to 180°, passing from North through West to South. In like manner, the declination is called East, if the direction of the north end of the needle is to the east of the geographical north, and is reckoned from 0° to 180°, passing from North through East to South. The positive and negative signs are also sometimes applied instead of the terms West and East, in which case + signifies West, and − East Declination.

The Inclination is counted positive, or has the sign *plus* prefixed, when the north end of the needle inclines below the horizon; and is counted negative, or has the *minus* sign prefixed, when the north end of the needle inclines above the horizon. Sometimes, instead of the signs + and −, the terms North and South are used, in which case North Inclination or Dip is when the north end of the needle dips below the horizon, and South Inclination or Dip is when the south end of the needle dips below the horizon. Thus an Inclination of − 30° is equivalent to 30° South Dip.

9. The Declination is measured by the azimuth compass, an instrument too well known to naval officers to require any description here, or any directions for the method of observing with it either on land or at sea. As made on the plan recommended by the Committee for the Improvement of Ships' Compasses, the azimuth compass in the hands of a careful observer, attentive to the practical rules published by the Admiralty for ascertaining the deviations of the compass caused by the iron of a ship, will give results, both at sea and on land, which leave little to be desired. For those who may desire to observe the Declination *on land* with yet superior accuracy, an apparatus is supplied with the Unifilar Magnetometer, for the use of which additional apparatus directions are given at the close of Appendix No. 1.

The use of the dipping needle (which measures the Inclination) not being so generally familiar to naval officers, full directions for its employment are given in Appendix No. 2.

Local Attraction.

10. It has been found that the results of magnetic observations, whether of the declination, inclination, or the intensity of the magnetic force, are liable to be influenced by local attraction proceeding from the rocks or soil in the vicinity of the instrument, and particularly so at stations where the rocks are of igneous character, such as traps, basalts, granites, &c. As a precautionary measure, therefore, magnetical instruments should always be used on stands which raise them 3 or 4 feet above the ground; and those stations are to be preferred of which the geological character is sedimentary or alluvial. Stations of igneous character, though less eligible for obtaining results which show the correct magnetical elements corresponding to the geographical position of the station, may nevertheless be serviceable as stations of comparison between the land and sea instruments; but for this purpose it is essential that the different instruments to be compared should be used precisely on one and the same spot at the station, in which case the local attraction may be supposed to be a constant quantity. And if the station be one frequently resorted to by vessels from which magnetic observations are made, it is desirable that the spot should be susceptible of a definite and well-recognisable description.

At sea, from the quantity of iron which a ship contains, it is scarcely possible that its influence on the instruments should be altogether avoided; but from the circumstance that the greater part of the most influential iron is in fixed positions in the ship, it has been proved by sufficient experience, that by a proper selection of the place in which a magnetic instrument is used on board ship, and by a certain process of observation (repeated whenever the ship has undergone any considerable changes of geographical position), the influence of her iron is susceptible of a sufficiently approximate calculation, and of being eliminated accordingly. Directions for the observations proper to be made for this purpose have been published by the Admiralty.

Summary of the Observations to be made.

11. An officer, therefore, who purposes to make magnetic observations, or to cause them to be made on board his ship, has to attend to the following points :—He must take care that he obtains the instruments some days before the ship is ready for sea, in order that he may assure himself that they are all complete, and that, if inexperienced in their use, he, or the observer whom he selects, may have some preliminary practice with them. He will then have to determine the constants, index corrections, &c. (unless these shall have been furnished with the instruments), and to make the observations required for a base station, with the needles which are to be employed in the relative determinations of the magnetic force and dip at sea. Positions will then have to be selected on board for the standard compass, and for Fox's apparatus, and the pillar for the one, and the gimball stand for the other, fitted accordingly. When the ship is ready for sea, the observations which are directed in the Admiralty Instructions for ascertaining the deviations of the compass caused by the iron of the ship are to be made on board; and when the ship is swung for this purpose, the deviations of the dip and of the force must be also observed on sixteen, or at least on eight, principal points of the compass, with Fox's apparatus used at the spot selected for it.

This completes the preparations to be made before the ship's departure. Whilst at sea, the observations of dip and intensity described in Appendix No. 3, as well as those of the declination or variation by the standard compass, should be made daily, whenever the weather and other circumstances permit. Whenever the ship is in harbour, and time and opportunities are suitable, it is desirable that the instruments should be taken on shore, and used at a spot selected as least likely to be influenced by any local attraction; and that the declination, inclination, and absolute horizontal force should there be determined, and the comparative observations made with Fox's apparatus. If the ship has materially changed her geographical position since the last occasion when the deviations were ascertained, or if changes have been made in her equipment by which the deviations may have been affected, it is desirable that the process for their examination should be repeated; and lastly, the *harbour observations here described should not fail to be repeated whenever the ship finally returns to England.*

Record and Transmission of the Observations.

12. Blank forms are supplied for the entry of observations of all classes, and for the first or uncorrected calculation of those which require that process to be gone through at the time. It is desirable that the forms should be filled up in duplicate, and that one copy should be retained, and the other sent to England from time to time, as soon as circumstances make it convenient. On their arrival they should be immediately examined, and any suggestion to which they may give rise communicated at once to the observer.*

Application of the Results.

13. The observations when thus received require that the several corrections arising from the influence of the iron, the variations of temperature, the changes in the magnetic force of the magnets, and from various other sources, should be sought out, computed, and applied, and the true or corrected results finally derived. These form the materials from which it is intended to construct maps, showing the variations of the magnetic force, and of the magnetic direction in its two co-ordinates of inclination and declination, corresponding to the present epoch, over the whole surface of the globe. The variations of the three elements are shown on these maps, by lines connecting, for example, in the maps of the magnetic force, those points where the intensity is observed to be the same;—in the

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* This has hitherto been done on all occasions when practicable, and it is very desirable that it should always continue to be done.

maps of the inclination, those points where the inclination is observed to be the same;—and in the maps of the declination, those points where the declination is observed to be the same. These lines are known by the names of Isodynamic, Isoclinal, and Isogonic lines. The Isogonic lines, which form the maps of the declination (or variation charts), have a direct practical importance and value in navigation, which in a notice addressed to naval officers needs not to be dwelt on. In theoretical respects, the Isodynamic and Isoclinal lines are not less essential; the three form the basis of a systematic view of terrestrial magnetism, as it manifests itself to us on the surface of the globe.

The mode in which the results are made to contribute to the formation of these maps is the following:—The results of the three elements finally corrected are entered, each in its proper geographical position, on maps on a large scale, severally appropriated to the force, the inclination, and the declination. Each result has a small characteristic mark denoting the observer. When any portion of the globe is sufficiently covered by the results of observations in proper distribution, the isophænomenal lines are drawn for that portion of the globe in correspondence with the observations, with a free hand, but with a careful judgment, aided occasionally by a process of calculation which it is not necessary here to describe. From these maps tables of double entry are formed, having the latitude at the side, and the longitude along the top of the page, and the values of the magnetic elements corresponding to the several latitudes and longitudes are placed at the points of intersection. By proper care in the process, the step of forming the tables from the maps need involve no additional uncertainty whatsoever. Maps and tables thus prepared will, when completed, form an experimental theory of terrestrial magnetism, in which the facts of nature will be shown with greater or less exactness, in proportion as the observations are numerous, correct, and suitably distributed, and as they are more or less correctly represented in the maps. Mathematical formulæ, based on general mathematical views, having numerical coefficients of which the values are derived from these maps, may also serve for the computation of the magnetic elements at *any* geographical position on the surface of the globe; and if the points taken from the maps to serve as the basis of the numerical values of the coefficients are sufficiently numerous, and have a proper distribution over the surface of the globe, and if the formulæ are carried to a sufficient number of terms, it may be expected that the elements computed from them will have the same degree of exactness as the maps from which their coefficients are taken.

It may be natural at this stage to inquire what prospect exists of being able to complete a work of this magnitude within a reasonable time; and to this question a more satisfactory reply can be returned than may perhaps be generally anticipated. Nearly three-fourths of the surface of the globe being covered by the ocean, it is chiefly by naval surveys that the materials for such a work can be collected. By the zealous and unwearying assiduity of British officers, acting under the sanction and with the approval of the Lords Commissioners of the Admiralty, and in some instances in expeditions specially appointed for the purpose, magnetic observations designed expressly for the object above-mentioned, and conducted upon a uniform system, have been extended in late years over nearly all the accessible parts of the ocean. Of these surveys, the results of some have been already deduced and published in the Philosophical Transactions, the expense of publication having been borne conjointly by the Government and by the Royal Society; and the results of others are undergoing the process of calculation and arrangement for publication. Whilst this more exact and careful elaboration of the results of the great mass of materials which have been accumulated is in progress, provisional maps of each of the three elements corresponding to the epoch of 1840, between the geographical latitudes of 60° N. and 60° S., have been constructed from a preliminary and general examination and co-ordination of the surveys. By an arrangement with Mr. Keith Johnston, these maps have been published in Plate 23 of the 2nd edition of the 'Physical Atlas,' accompanied by a brief exposition of the principal steps by which the knowledge we possess of the facts of the magnetic direction and force at the surface of the earth has been acquired. Copies of these maps and of the accompanying exposition may be obtained, separately from other subjects treated of in the Atlas, by application through any bookseller to Messrs. Blackwood of Edinburgh.

In prosecuting a work of this general and purely experimental character, unconnected with hypothesis of any sort, the phenomena of all parts of the globe must be viewed in the abstract as possessing an equal importance; and it does not appear desirable, therefore, to name any one of the lines, whether isogonic, isoclinal, or isodynamic, as deserving the special attention of observers in preference to others. There is one direction, however, which may be safely given, and which it may be well to remember at all times, viz., that "the value of each new station is directly proportional to its distance from those where observations have already been made;" and in this point of view it may be useful to notice, that up to the present time fewer observations have been made in the Pacific than either in the Atlantic or the Indian Ocean.

APPENDIX No. 1.

DESCRIPTION AND USE OF THE UNIFILAR MAGNETOMETER.

The Unifilar Magnetometer consists of two parts—an apparatus for deflection, and an apparatus for vibration: these correspond with the two parts of the process by which the absolute horizontal force is determined; the experiments of deflection consist in observing the angular deflection of a suspended magnet produced by the influence of a second magnet, which is placed on a support at one or more known distances from the suspended magnet, and in a line drawn from its centre perpendicular to its direction: the experiments of vibration consist in suspending the magnet which was used as the deflecting magnet in the experiments of deflection, and observing its time of vibration. By the first part of the process (or the experiments of deflection) we obtain the *ratio* of the magnetic moment of the deflecting magnet to the Earth's horizontal magnetic force at the place of observation; the latter being to the former as 1 to the sine of the angle of deflection multiplied by half the cube of the distance employed;—or if m denote the magnetic moment of the needle, X the Earth's horizontal force, r the distance apart of the centres of the magnets, and u the angle of deflection, the expression is—

$$\frac{m}{X} = \tfrac{1}{2}\, r^3 \sin u \left(\frac{1}{1 + \frac{P}{r^2} + \&c.}\right)$$

P being a constant depending upon the distribution of magnetism in the two magnets employed, and which may be determined by observations of the angle of deflection at two or more distances.

By the second part of the process (or the experiments of vibration) the *product* of the same two quantities is obtained: being the quotient of a constant, which we may call $\pi^2 K$ (see p. 104), divided by the square of the time of vibration: or if T be the time of vibration,

$$m\,X = \frac{\pi^2 K}{T^2}$$

The values of $m\,X$ and $\frac{m}{X}$ being known, those of m and X may be obtained separately: for if we call $m\,X = \alpha$ and $\frac{m}{X} = \beta$, m (the magnetic moment) $= \sqrt{\alpha\,\beta}$, and X (the horizontal component of the Earth's magnetic force) $= \sqrt{\frac{\alpha}{\beta}}$.

A. *Observations of Deflection.*

1. Place the circle upon the tripod-stand; attach the arm carrying the reading telescope and scale, the counterpoise weight, the suspension tube and thread, and the deflection-rod. Level the apparatus by means of the level attached to the circle. Suspend the brass plummet, and allow it to come to rest, turning the torsion-circle at the top of the suspension-tube until the marked side of the lower suspension-pin is towards the north. Remove the plummet and suspend the magnet, with the mirror facing the telescope, taking care that no torsion is introduced into the thread. Observe whether the magnet hangs horizontally, and, if not, move the sliding rings upon it until it does. Adjust the magnet to the same height as the deflecting magnet when

placed upon its supports; this is done by viewing it through the sight-tube placed upon the carriage intended to support the deflecting magnet upon the deflection-rod. Close the sides of the box; if the divisions of the scale are seen too high or too low in the field of the telescope, the inclination of the magnet-mirror may be corrected by means of the adjusting screws attached to it for the purpose.

2. Place the deflecting magnet in its stirrup upon its carriage at the distance 1·0 foot to the East of the suspended magnet, and with its north end towards the East. Turn the circle in azimuth until the middle division of the scale is bisected by the wire of the telescope; it will be necessary in this operation to make use of a small magnet (such as the screw-driver or steel lever magnetized) for the purpose of bringing the magnet to rest. Clamp the circle, read the verniers, and record the temperature of the magnet, as shown by a thermometer placed on the circle.

3. Reverse the magnet with its carriage, and place it at the same distance 1·0 foot East, north end to West. Turn the circle in azimuth as before, until the wire again bisects the middle division of the scale, read off the verniers and thermometer.

4. Remove the deflecting magnet with its carriage to the West side of the suspended magnet, and place it with its centre at the same distance as before, viz. 1·0 foot West, north end to West. Observe as before.

5. Reverse the magnet with its carriage, and place it at the same distance, 1·0 foot West, north end to East.

6. Take a mean of the circle-readings in the 1st and 4th positions of the deflecting magnet, and another mean of the readings in the 2nd and 3rd positions; half the difference of these means will be the angle of deflection required.

7. The operations above described should always be repeated *at least* twice, so as to obtain two separate values of the angle of deflection. If these values differ more than 30″ or 40″, a third set of observations should be taken. The value of the angle of deflection should be always deduced on the spot, so as to guard against accidental errors. As this can be done in two or three minutes, the precaution should never, if possible, be neglected.

8. When time permits, deflections should be observed alternately at the distances 1·0 and 1·3 foot; from a sufficient number of such pairs of deflections the quantity P may be calculated.

9. The arc-value of the scale divisions may be readily obtained thus: The magnet being brought to a state of rest, with the wire of the telescope cutting one of the divisions near one extremity of the scale, read the verniers. Move the circle until a division near the other extremity is bisected, and again read the verniers. The angle through which the circle has been turned, divided by the corresponding difference in the scale-readings, is the value of one division. This process

applies also to the collimator magnets employed for observations of vibration and declination.

B. *Observations of Vibration.*

1. Dismount the suspended magnet from the Unifilar Magnetometer, remove the suspension-tube, the arm carrying the telescope and scale, the counterpoise weight, and the deflection-rod. Screw into the place previously occupied by the suspension-tube the wooden frame carrying the vibration-box, the telescope, and the mirror; insert the thermometer, and attach the suspension-tube and thread for vibration; suspend the plummet and remove the torsion approximately from the thread; attach the deflecting (collimator) magnet; level, by means of the telescope-level and the cross-level on the top of the box; turn the circle in azimuth until the middle division of the magnet-scale is cut by the wire of the telescope when the magnet is brought to rest. Cause the magnet to vibrate through an arc extending to about 60′ on each side of the middle line of the scale, and observe the time of vibration in the following manner.

2. Determine roughly (to the nearest second) the time required by the magnet to make 10 oscillations. When observing with a pocket chronometer which beats 10 times in 4 seconds, watch the movement of the scale as the north end of the magnet moves towards the *East.* Count the first beat of the chronometer *after* the central division has passed the wire as 1, and continue the counting 2, 3, &c., to 10. At the 10th beat note the reading of the chronometer (which will thus be 4 seconds after the actual time) as the time* of the central division passing the wire at the 0th vibration. Add to the number now written down the approximate time for 10 oscillations, deduct 7 seconds from the sum, and, when the chronometer points to the resulting time, place the eye to the telescope and note the next passage of the central division across the wire in the same direction as before. This is the 10th vibration. Again, calculate the expected time of the 20th vibration, and observe as before, and so on till the 50th. From the 50th vibration calculate in like manner the expected time of the 60th: in this case, however, on placing the eye to the telescope, allow the passage of the central division to go unobserved, and take the next passage, which will be in the opposite direction, or north end of magnet moving West. This is the 61st vibration, from which calculate the time for the 71st, and so on till the 111th. There is now an

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* The observations may be taken to one-tenth of a second by estimating the relative distances of the central division of the scale from the wire at the chronometer beat *before* and the beat *after* the central line passing the wire; that is the 0th and 1st beat as counted. An expert observer may find it more convenient, instead of following the order of observation detailed above, to observe the 0th, 5th, 10th, 15th, &c., to the 55th vibration, and again the 200th, 205th, &c. In high magnetic latitudes, where the time of vibration becomes so great that 300 oscillations cannot be obtained at once, it will be better to observe thus, and to take 100 instead of 200 oscillations.

interval of some minutes, during which the observer may, from the observed interval between the 0th vibration and the 50th and between the 61st and 111th, calculate the approximate time for the 200th and 261st vibrations; the 200th, 210th, &c., and the 261st, 271st, &c., being observed in the same manner as the earlier vibrations. Subtract the time of the 0th vibration from that of the 200th, the 10th from the 210th, &c., and the 50th from the 250th. This will give six independent values of the time of 200 oscillations, the north end of the magnet moving East. Similarly subtracting the 61st from the 261st, the 71st from the 271st, &c., we have other six values for the time of 200 oscillations, the north end of the magnet moving West; the mean of the two series divided by 200 will give an exact value for the time of one oscillation.

3. Observe the reading of the thermometer at the commencement and termination of the series of observations. If the arc of vibration does not exceed the amount stated above, no correction on that account is required. The rate of the chronometer should be approximately stated.

4. The torsion force of the suspending thread is determined as follows. After having completed the observations of vibration, bring the magnet to rest and observe the scale-reading a. Turn the torsion circle through + 90°, the numbers on the torsion circle increasing; observe the scale-reading b; turn back to the original position, and read the scale a'; turn through − 90° (the numbers diminishing), and read the scale c; finally, turn to the original position and read the scale a''. Then $b - \frac{a + a'}{2} =$ effect of $+ 90^\circ$, and $c - \frac{a' + a''}{2} =$ effect of $- 90^\circ$: the arithmetical mean of these two quantities, multiplied by the arc-value of one scale division, is the effect of 90° of torsion in minutes.

5. The deflecting magnets now employed are collimator magnets, having double scales, the one (a short scale) being at right angles to the principal scale. When the line of collimation of the reading telescope (which has a level attached) is horizontal, the horizontal wire ought to cut that point of the short vertical scale which has been found to correspond with the magnetic axis of the magnet. This point may be found at first by making the short scale horizontal, and determining the magnetic axis by reversal in the manner afterwards described for the declination magnet. This point having been once determined, the magnet may be levelled at any time by sliding it in its stirrup until the wire cuts the required point of the vertical scale.

When properly adjusted, the magnet should be fixed firmly in its stirrup, and not removed again until a considerable change of geographical position necessitates a readjustment of the horizontality of the magnet.

C. *Calculation of the Value of the Horizontal Component of the Earth's Magnetic Force from Observations of Vibration and Deflection.*

T_0 = Observed time of one vibration of the magnet.

$T_{\prime}$ = Time of vibration, corrected for rate of chronometer and arc of vibration.

T = Time of vibration, corrected for rate of chronometer, arc of vibration, torsion force of the suspending thread, temperature, and induction.

s = Daily rate of chronometer, + when gaining, − when losing.

α, α' = Semiarc of vibration, at the beginning and end of the observation, expressed in parts of radius.

$\frac{H}{F}$ = Ratio of the force of torsion of the suspending thread to the magnetic directive force. [This is obtained from the formula $\frac{H}{F} = \frac{u}{90^\circ - u}$, where u = the angle through which the magnet is deflected by a twist of 90° in the thread.]

q = The correction for the decrease of the magnetic moment of the magnet produced by an increase of temperature of 1° Fah. [This correction is not constant at all temperatures, and the correction is more exactly expressed by a formula of the form,—correction to $t^\circ = q\,(t_0 - t) + q'\,(t_0 - t)^2$, t_0 being the observed temperature, and t an adopted standard temperature.]

K = Moment of inertia of the magnet, including its suspending stirrup and other appendages. [This is constant for the same magnet and suspension, but varies slightly with temperature, owing to the expansion of the materials.]

π = Ratio of the circumference to the diameter of the circle = 3·1415927.

μ = The increase in the magnetic moment of the magnet produced by the inducing action of a magnetic force equal to unity of the English system of absolute measurement.

r_0 = Apparent distance between the centres of the deflecting and suspended magnets in the observation of deflection.

r = Distance corrected for error of graduation and temperature.

$[r = r_0 \{1 + 0{\cdot}00001\,(t_0 - 62)\}$ + Correction for scale error.]

u_0 = Observed angle of deflection.

P = A constant depending upon the distribution of magnetism in the deflecting and suspended magnets. [This is to be determined from several series of observations of deflection at two or more distances. The most convenient distances to be employed for this purpose are 1·0 and 1·3 foot. The correction is small, and may remain unapplied until the conclusion of the series.]

m = Magnetic moment of the deflecting or vibrating magnet.

X = Horizontal component of the earth's magnetic force.

$\frac{m_0}{X_0}$ = Approximate value of $\frac{m}{X}$.

$\frac{m'}{X'}$ = Value of $\frac{m}{X}$ before the application of the correction $\left(1-\frac{P}{r_0^2}\right)$

$$T_, = T_0\left\{1-\frac{s}{86400}-\frac{\alpha\alpha'}{16}\right\}. \quad T^2 = T_,^2\left\{1+\frac{H}{F}-q\,(t_0-t)+\mu\frac{X_0}{m_0}\right\}$$

$$mX=\frac{\pi^2 K}{T^2}$$

$$\frac{m_0}{X_0}=\tfrac{1}{2}r^3\sin.u_0. \quad \frac{m'}{X'}=\frac{m_0}{X_0}\left\{1+\frac{2\mu}{r_0^3}+q\,(t_0-t)\right\}. \quad \frac{m}{X}=\frac{m'}{X'}\left(1-\frac{P}{r_0^2}\right).$$

Let A = value of $\frac{m'}{X'}$ from deflection at the distance r,

and A′ = ,, ,, r';

then $$P=\frac{A-A'}{\frac{A}{r^2}-\frac{A'}{r'^2}},$$

The quantity K is obtained by observing the time of vibration of the magnet alternately with its usual mounting, and with its moment of inertia increased by the addition of a gun-metal ring or cylinder of known weight and dimensions.

When a cylinder is employed, the value of K is obtained from the formula $K = W\left(\frac{l^2}{12}+\frac{d^2}{16}\right)\frac{t^2}{t'^2-t^2}$, where W is the weight of the cylinder in grains, l and d its length and diameter expressed in feet; t' and t being the times of vibration (corrected for torsion, temperature, &c.) of the magnet with and without the additional weight.

When a ring is employed the formula becomes

$K = W\left(\frac{r_i^2+r_e^2}{2}\right)\frac{t^2}{t'^2-t^2}$, r_i and r_e being the internal and external radii of the ring.

D. *Observations of Declination with the Unifilar Magnetometer.*

1. Remove the vibrating magnet and suspend the declination collimator magnet in its stead, after having carefully removed the torsion from the suspension-thread. Carefully level the apparatus until the axis of the mirror is exactly horizontal, as shown by the riding-level (which ought to be reversed in the operation) in all azimuths, but especially when the telescope is directed towards the sun's position.

2. Raise the magnet by the rackwork motion until the line of vision of the telescope is clear through the magnet-box. Move the circle in azimuth and the transit-mirror in altitude until the sun is visible in the telescope. Clamp the circle, and observe the times at which both

limbs of the sun pass the wire of the telescope; read the verniers; reverse the transit-mirror in its bearings, and repeat the observation of the sun's passage over the wires, and again read the verniers.

3. Lower the magnet; move the circle in azimuth until the scale of the magnet is in the field of the telescope; steady the magnet, and by the tangent-screw bring the wire of the telescope as exactly as possible to the zero division of the scale (or the point of the scale corresponding to the magnetic axis of the needle); read the verniers, noting also the time approximately.

4. When time permits, repeat the operations (2 and 3) until a good mean result is obtained. The more frequently and at the longer intervals the operation (3) is repeated, the greater will be the probability that the diurnal variation is eliminated. The hours best adapted for observations of the declination are 7 to 10 A.M., and 4 to 6 P.M., as at these times the magnet is nearly in its mean position, and the sun is most advantageous for observation.

5. From the operation (2), knowing the time at the place, the latitude of the place, and its approximate longitude, the Sun's azimuth may be computed, and the circle-reading corresponding to the astronomical meridian determined. From the operation (3) the circle-reading corresponding to the magnetical meridian is directly given. The difference between the computed circle-reading for the astronomical meridian and that obtained for the magnetical meridian is the Magnetic Declination.

6. Before commencing a series of observations, and occasionally when opportunity offers in the course of the series, it is necessary to determine very exactly the zero point of the scale, or the reading of the scale corresponding to the magnetic axis of the magnet. This is done as follows: suspend the magnet loosely in its stirrup, with the scale erect; move the circle until the divisions near the middle of the scale are in the middle of the field of the telescope. Clamp the circle firmly, and note the scale-reading. Invert the magnet in its stirrup (that is, turn the magnet on its horizontal axis through 180°), the circle remaining clamped; read the scale. Again invert, and repeat the operation several times, until a good mean is obtained. Having obtained say 5 observations, "scale erect," and 4 observations, "scale inverted," the zero point of the scale is—

$$\tfrac{1}{2}\left\{\begin{array}{l}\text{mean of readings, “scale erect”}+\\ \text{mean of readings, “scale inverted.”}\end{array}\right\}$$

This quantity ought to be constant for the same magnet; but care should be taken that neither the scale nor lens of the magnet is unscrewed or otherwise altered. If any doubt should exist as to the constancy of the zero point, the magnet should be inverted at each observation.

7. The torsion of the thread should be removed at every possible opportunity. This is done by removing the magnet, and substituting

a brass bar of *equal weight*, allowing the bar to hang until it has assumed a steady position, and turning the top of the suspension-tube until the bar hangs steadily in the line of the telescope. The magnet may then be replaced and fixed in its stirrup for observation, the scale being always made horizontal and the divisions erect. In replacing the magnet, care should be taken that a turn or half turn of torsion is not introduced into the thread. In carriage, and when the magnet is not in use, the magnet is fixed by wooden blocks in its box in such a way that torsion cannot readily be introduced. Whenever time allows, the torsion should, however, be removed.

8. There are three adjustments required for the transit-mirror :—

1st. The axle to which the mirror is attached must be horizontal. This adjustment is performed by means of a riding-level.

2nd. The mirror must be parallel to the axis of the cylindrical axle to which it is attached. This adjustment is made by means of a screw at the back of the mirror, as follows :—Turn the circle so that any well-defined object sufficiently elevated can be reflected into the telescope. Bisect the object by the wire of the telescope; reverse the axis, and observe whether the object remains bisected by the wire; if not, by the adjusting screw alter the inclination of the mirror until it is half the distance from the wire. Reverse again and again, until the object remains bisected before and after reversal of the axis.

3rd. The line of collimation of the telescope must be perpendicular to the axis. Having made the first two adjustments, this adjustment may be made thus :—Suspend a plumbline of some length in a sheltered position, or, if possible, within a house (the weight should swing in water to prevent oscillation). Turn the circle until the wire bisects the plumbline, as seen directly; read the circle and turn it through exactly 180°. Observe whether the upper part of the plumbline, when reflected into the telescope, coincides with the wire; if not, the adjusting screws must be moved until it does. In this operation it will be necessary to remove the magnet-box and suspension-tube. When this adjustment is completed, the adjusting screws ought to be fixed as tightly as possible.

In the instruments most recently constructed, the telescope is furnished with a collimating eyepiece, by which, when the plane of the transit-mirror is vertical, the image of the wire of the telescope will be seen by reflection from it. By means of the proper adjusting screws, both the second and third adjustments may be effected, by making the wire seen directly coincide with its image seen by reflexion before and after reversal of the transit axis. Both these adjustments can thus be readily verified before each observation.

APPENDIX No. 2.

OBSERVATIONS OF THE INCLINATION AND TOTAL FORCE, WITH BARROW'S CIRCLE FURNISHED WITH MICROSCOPES AND VERNIERS.

A.—*Inclination.*

1. PLACE the instrument on a tripod stand, and level it by means of the foot-screws; then bring the vertical circle into the magnetic meridian by the following process:—Place the needle designed for the observation of the dip on the agate supports, with the side of the needle on which the letters are inscribed facing the microscopes. Turn the vernier plate so that the microscopes may be nearly in a vertical line; clamp the plate, and set the lower vernier to 90° by the tangent screw. Turn the vertical circle in azimuth, so that its face may be towards the South, and until the North pole of the needle is bisected by the wire of the microscope; raise the Y's and lower gently; if the bisection of the needle has been altered, correct by turning the circle in azimuth. Clamp the horizontal circle, and read off its vernier, calling the reading A. Now set the upper vernier to 90°, unclamp the horizontal circle, and move in azimuth (if required) until the South pole of the needle is bisected by the wire of the upper microscope. Raise the Ys and lower gently; correct the bisection (if necessary) by moving the circle in azimuth; clamp the horizontal circle and read its vernier, calling the reading B. Now unclamp the horizontal circle, and turn the vertical circle 180° in azimuth, so that its face (by which is meant the side on which the microscopes are) which was before to the South may now be to the North. Repeat the process described above, which will give two other readings of the vernier of the horizontal circle, which call C and D. Then

$$\frac{A+B+C+D}{4} = E:$$

E being the division of the horizontal circle to which the vernier should be set, in order that the plane of the vertical circle may be at *right angles* to the magnetic meridian; therefore, when the vernier is set to 90 + E, the plane of the vertical circle will coincide with the magnetic meridian.

2. The vertical circle being now placed in the magnetic meridian, with its face to the *east*, and the marked side of the needle towards the face of the instrument, the needle will direct itself approximately to the inclination; raise it by the Y's, and lower it gently on its supports; repeat this operation two or three times before commencing to record the readings; bring the lower microscope to bisect the north end of the needle, clamp and adjust exactly by the tangent-screw, and read off the vernier. By means of the tangent-screw of the vernier-plate bring

the upper microscope to bisect the south end of the needle, and read its vernier; raise the Y's, and lower gently; repeat the readings, commencing now with the south end. The mean of the four readings is the inclination: *poles direct; face of needle to face of instrument; face of instrument east* = a.

3. Turn the vertical circle 180° in azimuth, and repeat the process of No. 2, taking again the mean of the four readings, which will be the inclination: *poles direct; face of needle to face of instrument; face of instrument west* = a'.

4. Reverse the needle on its bearings, and observe as before: *poles direct; face of needle reversed; face of instrument west* = a''.

5. Turn the vertical circle 180° in azimuth, and observe: *poles direct; face of needle reversed; face of instrument east* = a'''. The inclination, *poles direct*, will then be

$$\alpha = \frac{a + a' + a'' + a'''}{4}.$$

6. The poles of the needle must now be reversed by means of the bar magnets, by the following process:—Take the needle off the agates, holding it by the end which in the preceding observations was a South pole, and which is now to be converted into a North pole; place it with the flat side (which is lettered) uppermost in the wooden frame designed to prevent any injury occurring to the axle, being careful that the end to be made a North pole is placed towards that part of the wooden frame which is marked accordingly; secure the needle by the brass centre-piece, and place the frame with one end towards the right hand and the other towards the left. Now take the bar-magnets, one in each hand, and let the *North* pole of the bar-magnet be lowermost in the hand which is towards the end of the frame in which that end of the needle is placed which is to be made a *South* pole; and let the *South* pole of the bar-magnet in the other hand be lowermost. Draw the magnet about ten times along the flat side of the needle: the North pole of one bar-magnet being drawn along the end of the needle which is to be made a South pole; and the South pole of the other bar-magnet bêing drawn along the end of the needle which is to be made a North pole. The needle must then be turned over in the wooden frame, so that its other flat side may become uppermost, which must also be rubbed by the magnets ten times in the manner already described.

The bar-magnets should be held one in each hand, nearly in a vertical position, the lower ends resting on the needle; and must be drawn along the grooves in the wooden frame from near the centre to beyond the ends of the needle. When the process thus described has been gone through, it will be found, on replacing the needle on the agates, that the end which previously dipped below the horizontal line is now inclined above it.

7. The observations described in Nos. 2, 3, 4, and 5, must now be repeated, which will give four other mean readings, b, b', b'', b'''. The inclination with the *poles reversed* will then be

$$\beta = \frac{b + b' + b'' + b'''}{4};$$

and the *true* Magnetic Inclination of the place of observation will be

$$\theta = \frac{\alpha + \beta}{2}.$$

8. Two such determinations will generally be found sufficient; but if the results differ from each other more than 3′ or 4′ it is desirable to repeat the observations.

9. On arriving at a new station it is always desirable to magnetise the needle afresh before the observations are commenced. It is indifferent whether an observation is commenced with the end marked A as a North or as a South pole; but it is convenient to call that state of the needle in which the end A is a South pole, and the end B a North pole, "poles direct," and *vice versâ*.

B.—*Total Force.*

1. Dr. Lloyd has recently suggested a mode of employing the dip-circle for measuring the variations of the total force independent of changes in the magnetic moments of the needle or needles employed. For this purpose the instrument is furnished with two additional needles, which may be called for distinction Nos. 3 and 4, *the poles of which are at no time to be reversed or disturbed;* Nos. 1 and 2 being the needles used for observing the inclination in the usual way. No. 3 is an ordinary dipping needle; No. 4 is a similar needle loaded with a small fixed and constant weight, acting in opposition to magnetism. The frame, carrying the microscopes of the circle, is also fitted to receive and to retain No. 4 securely in a constant position, when it is used as a deflector of No. 3.

2. The observations consist of two processes; by the one process the position of equilibrium is observed of No. 3 between the action of the earth's magnetism, and that of No. 4 used as a deflector, having its North pole directed alternately towards the magnetic North and South; and by the other process the position of equilibrium of No. 4 is observed between the action of the earth's magnetism and that of the small constant weight with which it is loaded.

3. The observations for the inclination and total force may be conveniently taken in the following order:—

1°. Needle No. 1 is to be placed on the agate planes, and a complete observation of the inclination taken with it in the manner already described.

2°. Needle No. 3 is now to be substituted for No. 1, and No. 4 firmly attached to its supports between the microscopes, and always in the same position. The inclination of No. 3 to the horizon is then to be observed in one position of the needle and circle. The observation is to be repeated with the north end of No. 4 turned in the opposite direction by the revolution of the moveable arms which carry the microscopes; half the difference of the readings in the two positions is the angle of deflection u'.*

3°. Needle No. 3 is now to be removed, and the loaded needle, No. 4, substituted; and its inclination to the horizon, η, is to be observed in the four positions of the needle and circle. The deviation of this needle from the position due to the earth's magnetic force alone is $u = \theta - \eta$, the angle η being *positive* (+) when measured at the same side of the horizontal line with θ, and *negative* (−) in the contrary case.

4°. Repeat the observations (2°).

5°. Make a complete observation of the inclination with needle No. 2.

4. The value of the total force is given by the formula—

$$R = A \sqrt{\frac{\cos \eta}{\sin u \sin u'}}, \quad \text{where} \quad A = \frac{X}{\cos \theta} \sqrt{\frac{\sin u \sin u'}{\cos \eta}}$$

as observed at a base station, where X (the horizontal component) has been determined with the unifilar magnetometer, and the inclination θ has been also observed.

5. The method now described is, however, only applicable to a limited portion of the globe, being especially useful in the higher magnetic latitudes, and cannot be applied (without a readjustment of the loaded needle at a fresh base station) to the opposite hemisphere. If, however, the instrument is furnished with a needle such as those employed in Mr. Fox's apparatus (described in Appendix No. 3), in which the weight is attached to a fine thread passing round a light pulley, whose centre is on the axis of the cylindrical axle of the needle, the method becomes universally applicable. The above formulæ then become

$$R = A \sqrt{\frac{1}{\sin u \sin u'}} \text{ and } A = \frac{X}{\cos \theta} \sqrt{\sin u \sin u'}.$$

6. By this means the absolute inclination and the total force relatively to its value at the base station where the constant A was determined, may both be ascertained by the dip-circle alone, without displacement or alteration of its adjustment.

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* When the circle (as is usually the case) is divided in quadrants, care must be taken in observations of deflection that when the needle is deflected beyond the *vertical* the difference of the observed reading from 180° must be taken as the true reading. When it is deflected beyond the *horizontal*, the observed circle reading is to be entered with the *negative* sign prefixed, in which latter case the mean deflection will be half the arithmetical *sum* of the observed readings.

APPENDIX No. 3.

DIRECTIONS FOR USING MR. FOX'S APPARATUS FOR OBSERVING THE MAGNETIC INCLINATION AND FORCE.

I.—GENERAL REMARKS.

IN fixing the gimball table, it is convenient that it should be so arranged that, when the apparatus is placed on it, the zero divisions of the horizontal circle should coincide with the fore and aft midship-line of the ship.

In preparing for an observation at sea, the circle should be turned in azimuth until the vernier of the horizontal circle shows an angle with its zero corresponding with the difference between the magnetic meridian and the course which the ship is steering. The plane of the circle will then coincide with the magnetic meridian, when the ship is steadily steered. When, from circumstances of weather, &c., the steerage is difficult, an assistant is required to indicate to the observer the times when the ship is steady on her course.

The apparatus is usually furnished with three or four needles, one of which is intended to be used on shore for the determination of the true inclination (when no special instrument is provided for the purpose) by the process previously described, Appendix 2, in which the poles are reversed. The other needles, which are intended for the intensity, are never to have their poles reversed, and care is to be taken not to place them inadvertently near other magnets or iron. Besides the needles, two other magnets are supplied to be used as deflectors. In replacing the needles and deflectors in the travelling box, care should always be taken that the poles of each occupy the places marked for them in the box.

It is desirable to use always the same needle at sea, and to keep it always mounted, clamping it before it is put away for the day; but in case of its undergoing any considerable deterioration from use or accident, one of the other intensity needles may be substituted for it.

When changing the needles at a land station, be very careful not to injure the jewels, or the terminations of the axles of the needles; when a needle is changed it is desirable to hold it chiefly by the grooved wheel; the pivot should first be put into the outer jewelled hole, and the opposite pivot should be carefully guided into the hole at the back whilst the bracket is screwed up.

With respect to the constant weights, it is desirable that the smallest angle of deflection produced by any of the weights employed should not be less than 30°. On account of possible instrumental irregularities it is usual to employ more constant weights than one, with differences between each of half a grain (as for example, 2 grains, 2½ grains, 3 grains, &c.). Great care is taken that all the weights which have the same nominal value should be equiponderant, but it is desirable, if possible, to preserve the same identical weights throughout the whole observations of the same relative series.

II.—Observations at Sea.

A.—*Inclination.*

1. *Direct Observation.*—The instrument having been placed on the gimball stand and levelled, and the plane of the circle made parallel to the magnetic meridian, with the face of the circle towards the East, release the needle, which will immediately take approximately the direction of the inclination; rub gently the centre pin at the back with the ivory disk, and read off successively the divisions of the limb indicated by the two ends of the needle; note the readings, which will be +, or positive, when the North pole of the needle dips, and —, or negative, when the South pole of the needle dips: repeat the observation four times, turning the bracket which supports the needle a small quantity before each observation, and being careful to rub the centre pin at the back with the ivory disk whilst reading off. The bracket is turned by means of the screw-heads at the back of the circle, and the object of turning it is to cause the ends of the axle of the needle to have different points of bearing on the jewels in each observation. It is desirable, when four observations are taken, to turn the bracket (say) to the right before each of the first and third observations, and in the opposite direction before each of the second and fourth.

In reading the divisions on the limb, be careful always to bring the division nearest to the needle to coincide with the corresponding division of the second graduated circle immediately behind it, by which means parallax is avoided.

The mean of the four observations or eight readings above described is the apparent inclination by direct observation with the face East.

2. *Observation with Deflectors.*—Having made the preceding observation, screw in the deflector N (or the north pole of a second needle used as a deflector), and adjust the circle at the back by means of its verniers, so that the deflector may be 40° on one side of the division which in the preceding process (§ 1) was read off as the direct observation with the face East. The needle will then be repelled, and will settle on the opposite side of the dip. Read off (always whilst rubbing with the ivory disk) the divisions indicated by the two ends of the needle. Repeat the observation four times, altering the bearings of the ends of the axle before each observation as above directed. Turn the back circle through 80°, so that the deflector may be 40° on the other side of the apparent dip. Move the needle by the bracket, so that it may be deflected on the opposite side of the apparent dip to what it was before, and make four observations. The mean of the

eight observations or sixteen readings is the apparent inclination with a deflector, face East.

Instead of placing the deflector at 40°, another angle, as 45° or 50°, may be taken; or a second angle may be used for the purpose of varying the observations when it may be desired to repeat them; the only essential point being, that the angle at which the deflector is placed should be the same on each side the apparent dip.

Instead of deflector N (or the North pole of a second needle used as a deflector), deflector S (or the South pole of the second needle) may be screwed into the opposite point of the back circle, and eight observations taken with it will give as before the apparent inclination with a deflector, face East.

When time permits and the circumstances are favourable, the observations prescribed in (1) and (2) may be repeated with the face of the circle to the West.

In writing down the observations the following directions must be attended to; if the needle be deflected past the *vertical*, the division of the limb should be read off according to the graduation and noted accordingly, but the mean of the readings must be taken from 180°, in order to give the true arc corresponding to the position of the needle: if it be deflected past the *horizontal*, the readings must be entered as marked on the limb, but with the negative sign prefixed, in which case the mean result will be half the *difference* of the means of the negative and positive readings.

The apparent inclination obtained as above directed, whether by the direct method, or with deflectors, requires two corrections to give the true inclination, viz.—1st, the index-correction of the particular needle employed; and 2nd, a correction for the influence of the ship's iron dependent on the direction of her head at the time of observation. The mode of obtaining the index correction will be subsequently explained.

B.—*Intensity.*

3. *With Weights.*—The instrument being on the gimball table and levelled, the plane of the circle parallel to the magnetic meridian, with its face to the East, and the needle showing the magnetic dip, place the silk carrying the hooks on the grooved wheel; attach one of the constant weights to one of the hooks, and take four readings of the division of the limb at which the needle is in equilibrium, using the precautions already directed of altering the points of support of the axle before each observation, and rubbing with the ivory disk whilst reading off.

If the needle is deflected past the vertical or horizontal, read and enter the angles as already directed under the head of Inclination.

Change the weight to the other hook, when the needle will be deflected to the opposite side of the apparent dip to what it was before, and take four more observations. Half the difference of the mean of the arcs with the weight on either hook is the angle of deflection due to the constant weight employed; or half their *sum*, if one of the arcs was past the horizontal, and has therefore the negative sign prefixed.

4. *With Deflectors.*—The instrument being adjusted as already described (and without using the hooks, which are only designed for the observations in which the weights are used), adjust the circle at the back by means of its verniers to the apparent dip, so that the deflectors, when screwed in may coincide with the line of the dip; the needle will then be repelled to one side: make four observations of the division to which the needle is thus deflected, observing the usual precautions of moving the bracket at the back, reading both ends of the needle, and rubbing with the ivory disk.

Move the needle past the deflector to the other side of the dip by means of the bracket, and take four more observations: if the needle is deflected past the vertical or horizontal, read and enter the angles in the manner already described; half the difference of the arcs on either side of the apparent dip, or half their sum if one be past the horizontal and have the negative sign, will be the angle of deflection produced by the deflector. Instead of the deflectors, a second needle may be used as a deflector, either with the end of the needle-case marked N (containing the north pole of the needle) screwed into the arm marked N, or the end marked S screwed into the arm marked S.

The thermometer attached to the circle must be observed at the commencement and close of the observations of intensity, whether with deflectors or weights.

A convenient routine of the observations at sea may be stated as follows:—

1. Take four observations of the apparent dip by the direct observation.

2. Screw in the deflectors N and S, and adjust the back circle to the dip. Make four observations of the angle of deflection produced on either side of the apparent dip; this furnishes one result for the intensity of the magnetic force.

3. Repeat No. 2 with a second needle used as deflector N, which will give a second result for the intensity of the force.

4. Repeat No. 2 with the second needle used as deflector S, which will give a third result for the intensity of the force.

5. Remove the deflector and repeat No. 1, which will give a second result for the apparent inclination.

On days when the weather permits, observe the intensity also by the constant weights.

5. *Combination of Deflector and Weights.*—Addition by Mr. WELSH.

[The instruments most recently constructed under Mr. Fox's direction have been adapted for the method, devised by Dr. Lloyd, of measuring the variations of the total force independent of the changes in the magnetic moment of the needles employed. The method is described in Appendix No. 2. Two of the dipping needles used for observations of the intensity with weights are employed in this process, and their poles must never be reversed or disturbed. One of the needles, A, is mounted as a dipping needle, and another, B, precisely similar in its construction, is used as a deflector. The needle B, being attached to the frame * at the back of the instrument which carries the arms of the verniers, is thus moveable in a plane parallel to that of the dipping needle. In taking the deflections, the deflector must always be moved to such a position that it is exactly at right angles to the dipping needle when the latter has come to rest in its position of equilibrium between the earth's force and that of the deflecting needle. This is accomplished by setting (first approximately and afterwards exactly) the verniers at the back to the same circle reading as shown by the dipping needle. The position of the dipping needle is then to be accurately observed, the same precautions being adopted as have already been prescribed in other observations with this instrument. The frame carrying the deflector is then to be moved until the dipping needle A is deflected to the opposite side of the line of the inclination, and the deflector again set carefully at right angles to it in its new position. The position of the dipping needle having been exactly observed as before, half the difference between the readings in the two positions is the angle of deflection u' required. In this observation it is of most essential importance that the relative positions of the two needles in the observations made at different times and places should be identical. The following rule may be useful in placing the deflector on its supports:—Set the vernier A at the back to 90° at the top of the circle (the face of the instrument being towards the east); fix the deflecting needle (in its case) upon its frame *with the north pole towards the north*, keeping the lettered side of the case uppermost. The utmost care should be taken that the needle is always placed in its case in precisely the same way and with the poles in the same direction, and that it is there held firmly in its proper place by the springs provided for the purpose. The observations of deflection should be repeated at two or more different distances (distinguishing the distances by numbers).

The needle A must now be removed, and B substituted in its place, and a series of deflections *with weights* made with B. Needle A may then be used as a deflector, and a series of deflections of B made in the manner already described: needle A is then to be again mounted as at first, and observations with weights taken with it. This will give two complete sets of observations, one with each of the needles. The thermometer must be recorded for each operation.

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* By removing one of the supports for the deflecting needle which have been added to the instrument, and substituting for it a tube which is provided, the second needle may be mounted and used as a deflector in the manner formerly practised and described above. The grooved wheels of the needles are now, by Mr. Fox's directions, made of aluminium, which advantageously reduces their weight.

When the ship is on her voyage it may not be convenient or possible to perform all those operations at each observation. It may therefore be proper to arrange the order of observing as follows:—In the ordinary daily determinations of the inclination and force, observe—1st, the inclination in the usual manner with needle A (which we will suppose to be the needle in ordinary use); 2nd, deflections of needle A with weights; 3rd, deflections of needle A by needle B by the method now described; 4th, repeat the observation of inclination with needle A. It will be desirable, once in a month or six weeks, when weather and circumstances are favourable (and always on shore when opportunity offers), to go through the whole of the processes above described in the following order:—1st, observation of inclination with A; 2nd, deflections of A with weights; 3rd, deflections of A by B; 4th, deflections of B by A; 5th, deflections of B with weights; 6th, observation of inclination with B; 7th, observation of inclination with A. In exchanging the needles care should be taken to mount them always in one way, viz. with the pulley on the side next the observer. The third needle supplied with the instrument is a plain dipping needle, whose poles may be reversed, and which is intended to be used on shore as directed in Appendix No. 2.

6. *Calculation of the Observations; 1st, with Weights.*—Let R be the intensity, expressed either in absolute or relative measure, and u the angle of deflection produced by a constant weight at the base station; R_o and u_o being the intensity and deflection at any other station; then

$$R_o = \frac{C}{\sin u_o}\left\{1 + q\,(t_o - t)\right\}$$

where $C = R \sin u$, a constant; t_o the temperature of the needle at the second station; t that at the base station; and q the correction for the decrease of the magnetic moment of the needle produced by an increase of temperature of 1° Fahr., a quantity which must be experimentally determined at a fixed observatory for each needle.

2ndly. *With Deflector by Dr. Lloyd's Method.*—Let u' and u'_o be the angles of deflection at the base station and at any other station; then

$$R_o = \frac{D}{\sin u'_o}\left\{1 - q\,(t_o - t)\right\}$$

where $D = R \sin u'$, a constant; the other quantities having the same meaning as before.

3rdly. *By Combination of the two methods.*—When the observations with the deflector are combined with those with weights, *e.g.* when observations of deflection of *A with weights* and of *B by A* are taken at one time, the formula becomes

$$R_O = \sqrt{\frac{C\,D}{\sin u_O \sin u'_O}}$$

the effect of temperature being thus eliminated. The value of R_O will always be intermediate between the values derived separately from the two methods of deflection, and the difference (if any) will be a measure of the loss of magnetism of the needle between the observations at the two stations.

4$^{\text{thly}}$. *With Deflectors by the Original Method.*—Where deflectors are used in the manner hitherto adopted, that is, with the deflector placed at right angles to the plane of the instrument, the intensity is obtained by the formula

$$R_O = \frac{R\,w_O \sin v}{w \sin v_O}\left(1 - q\,(t_O - t)\right)$$

where R, v, and w are the intensity, angle of deflection, and equivalent weight at the base station; and R_O, v_O, and w_O those at any other station.

A table of "equivalent weights" may be formed in the following manner:—The plane of the instrument being placed perpendicular to the magnetic meridian, and the needle in its natural position of rest (which in such case is a vertical position), the deflector is placed successively at angles from the vertical, each differing one degree from the preceding: the needle is thereby deflected to an angle on the side of the vertical opposite to the deflector, and is brought back to its natural position of rest by weights applied to the grooved wheel on the axle. These weights are called the equivalent weights, corresponding to the angles from the vertical at which the deflector was successively placed, and which ought to include all the angles likely to occur in the course of the observations.]

III.—OBSERVATIONS ON SHORE.

1. The instrument being adjusted with the plane of the circle coinciding with the magnetic meridian, and the face East, make a complete series of observations of the Inclination with and without deflectors, and of the Intensity with the deflectors and weights, similar in all respects to the observations which have been or which are intended to be made at sea; the needle, deflectors, and weights to be those employed, or to be employed, in the sea-observations.

2. Repeat the same with the face West.

3. If unfurnished with a separate apparatus for determining the true inclination, substitute in Mr. Fox's apparatus the needle which admits of its poles being reversed (viz. that needle which is not intended to be

used in observations of intensity), and obtain the true inclination from the mean of the angles read in eight different positions of the instrument, following the order of observations described in Appendix No. 2. The difference between the true inclination thus obtained, and the apparent inclinations with the face East and West observed with the needle used at sea, ascertained at the several shore stations, furnish one of the data from which the index correction to be applied to the observations made at sea is to be computed.

4. When Mr. Fox's apparatus is furnished with more than one needle for the observations of intensity, each needle must be successively substituted in the shore observations for the needle used at sea, and the inclination as well as the angles of deflection with constant weights observed with it.

ARTICLE V.

SECOND DIVISION, SECTION 2.

METEOROLOGY.

BY SIR J. F. W. HERSCHEL, BART.

THERE is no branch of physical science which can be advanced more materially by observations made during sea voyages than meteorology, and that for several distinct reasons. 1st. That the number and variety of the disturbing influences at sea are much less than on land, by reason of the uniform level and homogeneous nature of its surface. 2ndly. Because, owing to the penetrability of water by radiant heat, and the perpetual agitation and intermixture of its superficial strata, its changes of temperature are neither so extensive nor so sudden as those of the land. 3rdly. Because the area of the sea so far exceeds that of the land, and is so infinitely more accessible in every part, that a much wider field of observation is laid open, calculated thereby to afford a far more extensive basis for the deduction of general conclusions. 4thly. The sea being the origin from which all land waters are derived, in studying the hygrometrical conditions of the sea atmosphere we approach the chief problems of hygrology in their least involved and complicated form, unmixed with those considerations which the perpetually varying state of the land (as the recipient at uncertain intervals of derivative moisture) forces on the notice of the meteorologist of the continents. Nor ought it to be left out of consideration that this, of all branches of physical knowledge, being that on which the success of voyages and the safety of voyagers are most immediately and unceasingly dependent, a personal interest of the most direct kind is infused into its pursuit at sea, greatly tending to relieve the irksomeness of continued observations, to insure precision in their registry, and to make their partial or complete reduction during the voyage an agreeable, as it always is a desirable object.

It happens fortunately that almost every *datum* which the scientific meteorologist can require is furnished in its best and most available state by that definite, systematic process known as the "*keeping a meteorological register*," which consists in noting at stated hours of every day the readings of all the meteorological instruments at command, as well as all such facts or indications of wind and weather as are susceptible of being definitely described and estimated without instrumental aid. Occasional observations apply to occasional and remarkable phenomena, and are by no means to be neglected; but *it is to the regular meteorological register, steadily and perseveringly kept throughout the whole of every voyage, that we must look for the development of the great laws of this science.*

The following general rules and precautions are necessary to be observed in keeping such a register:—

1. Interruptions in the continuity of observations by changes of the instruments themselves, or of their adjustments, places, exposure, mode of fixing, reading, and registering, &c., are exceedingly objectionable, and ought to be sedulously avoided. Whenever an alteration in any of these particulars is indispensably necessary, it should be done as a thing of moment, with all deliberation, scrupulously noted in the register, and the exact amount of change thence arising in the reading of the instrument (whether by alteration in its zero point, or otherwise) ascertained.

2. As far as possible, registers should be complete: but if, from unavoidable causes, blanks occur, no attempt to fill

them up subsequently from general recollection, or (which is worse, and amounts to a falsification) from the apparent course of the numbers before and after, should ever be made. The entries in the register made at the time of observation should involve no reduction or correction of any kind, but should state the simple readings off of the several instruments, and other particulars just as observed. This does not of course prevent that blank columns left for reduced and corrected observations should be filled up at any convenient time. On the contrary, it is very desirable that such should be the case—the sooner after the observation, consistently with due deliberation, the better, on every account, unless some datum be involved requiring subsequent discussion for its determination.

3. The observations of each kind should, if possible, all be made by one person; but as this is often impracticable, the deputy should be carefully instructed by his principal to observe in the same manner, and the latter should satisfy himself, by comparative trials, that they observe alike.

4. If copies be taken of registers, they should be carefully compared with the originals by two persons—one reading aloud from the original, and the other attending to the copy, and then exchanging parts—a process always advisable when great masses of figures are required to be correctly copied.

5. The registers should be regarded (if kept in pursuance of orders, or under official recommendation) as official documents, and dealt with accordingly. If otherwise, a verified copy, or the original (the latter being preferred), signed by the observer, should be transmitted to some public body interested in the progress of meteorological science, through some official channel, and under address "*To the Secretary of, &c. &c.*" Circuitous transmission hazards loss or neglect, and entails expense on parties not interested.

6. The register of every instrument should be kept in parts of its own scale as read off; no reduction of foreign measures or degrees to British being made. But it should

of course be stated what scale is used in each. British observers, however, will do well to use instruments graduated according to British units.

7. The regular meteorological hours are 3 A.M., 9 A.M., 3 P.M., and 9 P.M., mean time at the place. Irksome as it may be to landsmen to observe at 3 A.M., the habits of life on shipboard render it much less difficult to secure this hour in a trustworthy manner; and the value of a register in which it is deficient is so utterly crippled, that, whatever care be bestowed on the other hours, it must on that account hold a secondary rank. The hours above, it must be borne in mind, are the fewest which any meteorological register pretending to completeness can embrace. By any one, however, desirous of paying such particular attention to this branch of science as to entitle him to the name of a meteorologist, a three-hourly register—viz. for the hours 3, 6, 9, A.M., noon; 3, 6, 9, P.M., midnight—ought to be kept; and in voyages of discovery, where scientific observation is a prominent feature, the register ought to be enlarged, so as to take in every *odd* hour of the twenty-four; thus including, *without interpolation*, the six-hourly or standard series. Any series of hours which does not divide the twenty-four hours *equally* (*i.e.* into intervals equal to each other), is, in the present state of meteorological computation and knowledge, comparatively worthless.

8. Hourly observations should be made throughout the twenty-four hours on the 21st of each month (except when that day falls on a Sunday, and then on the Monday following), commencing with 6 A.M., and ending at 6 A.M. on the subsequent day, so as to make a series of twenty-five observations. At all events, if this cannot be done monthly, it ought not to be omitted in March, June, September, and December. These are called "term observations." If any remarkable progressive rise or fall of the barometer be observed to pervade this series, it will be well to continue it until the maximum or minimum is clearly attained, with a view to comparison with other similar series elsewhere obtained, and thus to mark the progress of the aërial wave

effective in producing the change. These term observations should be separately registered under that head.[*]

9. Occasional *hourly* series of observations may be made with advantage under several circumstances, as, for instance—1stly. When becalmed for any length of time, especially when near the equator, with a view to determining the laws and epochal hours of diurnal periodicity. 2ndly. When a party leaves the ship, furnished with a portable barometer or other instruments,[†] for the measurement of heights of mountains, or with other objects. 3rdly. During threatening weather, and especially during the continuance of gales, and for some time after their subsidence, as will be more particularly specified under the head of "Storm Observations." 4thly. In certain specified localities mentioned in the next article by Mr. Birt. 5thly. Whenever a *continued* rise or fall of the barometer has been noticed as at all remarkable, it should be pursued up to and past the turn, so as to secure the maximum elevation or depression, and the precise time of its occurrence; and a register of such maxima or minima should be kept distinct from the regular entries.

Of Meteorological Instruments; and first, of the Barometer and its attached Thermometer.

The barometer on shipboard should be suspended on a gimbal frame, which ought not to swing too freely, but rather so as to deaden oscillations by some degree of friction. Before suspending it, it should be carefully examined for air-bubbles in the tube and for air in the upper part above the mercury, by inspection, and by inclining the instrument from the vertical position rather suddenly till the mercury rises to the top with a slight jerk, when, if it do not *tap sharp*, the vacuum is imperfect; and if the sound be puffy and dead, or is not heard at all, air exists to an objectionable extent, and must be got rid of by inversion and gently striking with the hand to drive the bubble up into the cistern. The lower end of the tube, which plunges into the cistern in well-constructed marine barometers, is contracted so as to diminish the amount of oscillation produced by the ship's motion. The instrument should be suspended out of the reach of sunshine, but in a good light for reading, as near midships, and in a place as little liable to sudden changes of temperature and gusts of wind as possible. The light should have access to the back of the tube, so as to allow the index to be set with its lower edge forming a tangent to the convex surface of the mercury. In well-constructed barometers the slider has its lower part tubular, embracing the tube, and can be made to descend by the rack-motion of the vernier till it becomes an upper tangent to the mercury: the eye being on its exact level, a reflected light by day, or white paper strongly illuminated from behind at night, will throw the light properly for setting the vernier correctly. The exact height of the cistern above the ship's water-line should be ascertained and entered on the register.

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[*] The term observations have in a great measure fallen into disuse, a large mass of them having accumulated which require reduction and discussion. Before undergoing the trouble of making them, therefore, in any particular case, the observer would do well to secure co-operation from officers in other ships, or to inquire at what fixed stations they continue to be made.—R. M.

[†] The aneroid, if used in excursions of this kind, should be first accurately compared with the standard barometer; after which its indications would seem, from recorded trials, to be tolerably dependable as far as 2000 feet in altitude. The comparison should be repeated on returning.

The attached thermometer ought to indicate a temperature the exact mean of that of the whole barometric column. Its bulb, therefore, ought to be (though it seldom is) so situated as to afford the best chance of its doing so, that is to say, fifteen inches above the cistern, enclosed within the wooden case of the barometer, nearly in contact with its tube, and with a stem so long as to be read off at the upper level.* To ensure a fair average and steady temperature, it were well to enclose the whole instrument, thermometer and all, in an outer case of leather, over a wrapper of flannel, leaving only the setting and reading parts above and below accessible, and that no more than is absolutely necessary.*

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* In some of the best modern barometers the attached thermometer is blown in the same piece with the tube of the barometer, and this

In choosing a barometer, select one in preference in which the lower level (of the mercury in the cistern) is adjustable to contact with a steel or ivory fiducial point, and *that* not by altering the height of the mercurial surface, but by depressing the steel point *carrying down with it the whole divided scale*, the zero-point of which is of course the apex of the point itself. There should be a provision for clamping the scale in this position, to secure it from change while setting the upper index. Care should be taken that air have free but safe access to the lower surface.

In transporting a compared barometer to its place of destination great care is necessary. Carry it upright, or considerably inclined, and *inverted;* and over all rough roads, in the hand, to break the shocks it would otherwise receive. A "portable barometer" strapped obliquely across the shoulders of a horseman travels securely and well; and with common care in this mode of transport its zero runs no risk of change. If merely fastened to any kind of carriage, and abandoned to its fate, it is almost sure to be broken.

To make and reduce an Observation of the Barometer.—First read off and write down the reading of the attached thermometer. Then give a few gentle taps on the instrument to free the mercury from adhesion to the glass,

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affords, as I am informed by Mr. Glaisher, the best possible means of ensuring an exact knowledge of the temperature of the column of mercury.—R. M.

* For a permanently suspended or fixed barometer, the best thermometer would be one with a tubular bulb of equal bore and thickness of glass with the barometer tube, and extending in length from the cistern to the exposed face of the instrument, and as close to the barometric column as is consistent with the structure of the upper works. Immersion of the ball of the attached thermometer in the cistern is the worst arrangement of any.

avoiding to give it any violent oscillation. Adjust the lower level to the fiducial point, and clamp the scale, if such be the construction of the instrument. Then set the index to the upper surface of the mercurial column, placing the eye so as to bring its back and front lower edges to coincidence, and to form a tangent to the convexity of the quicksilver. If the instrument have no tubular or double-edged index, the eye must be carefully placed at the level of the upper surface to destroy parallax. Whatever mode of reading is adopted should be always adhered to. A magnifier should be used to make the contact and to read the vernier, and the reading immediately written down and carefully entered on the register.

As soon after the observations have been made as circumstances will permit, the reading of the barometer should be *corrected* for the relation existing between the capacities of the tube and cistern (if its construction be such as to require that correction), and for the capillary action of the tube; and then *reduced* to the standard temperature of 32° Fahr., and to the sea-level, if on shipboard. For the first correction the *neutral point* should be marked upon each instrument. It is that particular height which, in its construction, has been actually measured from the surface of the mercury in the cistern, and indicated by the scale. In general the mercury will stand either above or below the neutral point; if *above*, a portion of the mercury must have left the cistern, and consequently must have *lowered* the surface in the cistern: in this case the altitude as measured by the scale will be *too short—vice versâ*, if below. The relation of the capacities of the tube and cistern should be experimentally ascertained, and marked upon the instrument by the maker. Suppose the capacity to be $\frac{1}{50}$, marked thus on the instrument, "*Capacity* $\frac{1}{50}$:" this indicates that, for every inch of variation of the mercury in the tube, that in the cistern will vary contrariwise $\frac{1}{50}$th of an inch. When the mercury in the tube is *above* the neutral point, the difference between it and the neutral point is to be reduced in the proportion expressed by the "capacity" (in the case supposed, divided by 50), and the quotient *added* to the observed height; if *below*, *subtracted* from it. In barometers furnished with a fiducial point for adjusting the lower level, this correction is superfluous, and must not be applied.

The second correction required is for the capillary action of the tube, the effect of which is always to depress the mercury in the tube by a certain quantity inversely proportioned to the diameter of the tube. This quantity should be experimentally determined during the construction of the instrument, and its amount marked upon it by the maker, and is always to be *added* to the height of the mercurial column, previously corrected as before. For the convenience of those who may have barometers the capillary action of which has not been determined, a table of corrections for tubes of different diameters is placed in the Appendix, Table I.

The next correction, and in some respects the most important of all, is that due to the temperature of the mercury in the barometer-tube at the time of observation, and to the expansion of the scale. Table II. of the Appendix gives for every degree of the thermometer and every half-inch of the barometer, the proper quantity to be added or subtracted for the reduction of the observed height to the standard temperature of the mercury at 32° Fahr.

After these the index correction should be applied. This is the amount of difference between the particular instrument and the readings of the Royal Society's flint-glass barometer when properly corrected, and is generally known as the *zero*. It is impossible to pay too much attention to the determination of this point. For this purpose, when practicable, the instrument should be immediately compared with the Royal Society's standard, and the difference of the readings of both instruments, when corrected as above, carefully noted and preserved. Where, however, this is impracticable, the comparison should be effected by means either of some other standard previously so compared, or of an intermediate portable barometer, the zero-point of which has been *well determined.* Suspend the portable barometer as near as convenient to the ship's barometer, and after at least an hour's quiet exposure take as many readings of both instruments as may be necessary to reduce the probable error of the mean of the differences below 0·001 inch. Under these circumstances the mean difference of all the readings will be the *relative* zero or index error, whence, if that of the intermediate barometer be known, that of the other may be found. As such comparisons will always be made when the vessel is in port, sufficient time can be allowed for making the requisite number of observations: hourly readings would perhaps be best, and they would have the advantage of forming part of the system when in operation, and might be accordingly used as such.

It is not only desirable that the zero-point of the barometer should be well determined in the first instance; it should also be carefully verified on every opportunity which presents itself. And in the first instance, previous to sailing, after suspending the barometer on shipboard, it should be re-compared with the standard on shore by the intervention of a portable barometer, and no opportunity should be lost of comparing it on the voyage by means of such an intermediate instrument with the standard barometers at St. Helena, the Cape of Good Hope, Bombay, Madras, Paramatta, Van Diemen's Island, and with any other instruments likely to be referred to as standards, or employed in research elsewhere. Any vessel having a portable barometer on board, the zero of which has been well determined, would do well on touching at any of the ports above named to take comparative readings with the standards at those ports, and record the differences between the standard, the portable, and the ship barometers. By such means the zero of one standard may be transported over the whole world, and those of others compared with it ascertained. To do so, however, with perfect effect, will require that the utmost care should be taken of the portable barometer; it should be guarded as much as possible from all accident, and should be kept safely in the "portable" state when not immediately used for comparison. To transport a well-authenticated zero from place to place is by no means a point of trifling importance. Neither should it be executed hurriedly nor negligently. Some of the greatest questions in meteorology depend on its due execution, and the objects for which these instructions have been prepared will be greatly advanced by the zero-points of all barometers being referred to one common standard. Upon the arrival of the vessel in England, at the termination of the voyage, the ship's barometer should be again compared with the same standard with which it was compared previously to sailing; and should any difference be found, it should be most carefully recorded.

The correction for the height of the cistern *above* or *below* the water-line is *additive* in the former case, *subtractive* in the latter. Its amount may be taken, nearly enough, by allowing 0·001 in. of the barometer for each foot of difference of level.

An example of the application of these several corrections is subjoined:—

Attached Therm. 54°·3.

		in.
Barometer reading		29·409
Corr. for capacity	−	·017
		29·392
Corr. for capillarity ..	+	·032
		29·424
Corr. for temperature	−	·068
		29·356
Corr. for zero and water-line	+	·040
Aggregate = pressure at sea-level		29·396

Data for the Correction of the Instrument.

		in.
Neutral point		30·123
Capacity $\frac{1}{48}$		
Capillary action	+	·032
Zero to Royal Society	+	·036
Corr. for altitude above water-line	+	·004

Thermometers.—The observer should be furnished with a delicate and accurate thermometer, most carefully compared with a perfectly authentic standard, at several temperatures, differing considerably, and of which the freezing point has been most scrupulously verified. This he should keep *solely* as a thermometer of reference, and every thermometer he employs should be compared with it, so as not to leave a doubt as to the amount of their constant difference when exceeding a tenth of a degree. To make such comparisons, long rest, in contact, in a box stuffed with cotton, allowing only the portions of the scales where read off to be from time to time uncovered for that purpose, is the best mode of insuring their perfect identity of temperature. If, in any instance, the zeros differ in different parts of the scales, a table of reduction to the standard will require to be constructed. The comparisons should be repeated at not very distant intervals of time, especially in the case of self-registering thermometers, whose index-errors are constantly changing and require great watchfulness. In registering thermometers *record* but do not *apply* their zeros.

In placing the *External Thermometer*, an exposure should be chosen perfectly shaded both from direct sunshine, and that reflected from the sea, or radiated from any hot object. It should be especially guarded from rain and from spray, so that the bulb should never be wetted, also from warm currents of air and from local radiation; completely detached from contact with the ship's side, and fully exposed to the *external* air. In reading it the observer should avoid touching, breathing on, or in any way warming it by the near approach of his person; and in night-observations particular care should be taken not to heat it by approach of the light. The quicker the reading is done the better. At night it should be completely screened from the sky, so as to annihilate all loss of heat by upward radiation; a light frame-case of double wire-gauze will perhaps be found a secure and efficient protection both from injury and obnoxious influences.

The *Self-registering Thermometers* should be placed with the same precautions as the external thermometer, and in similar exposures, and so fastened as to allow one end to be detached and lifted; so that the indices within the tubes may slide down to the ends of the fluid columns, which they will readily do on gentle tapping. They are apt to get out of order by the indices becoming entangled, or by the breaking of the column of fluid. When this happens to the spirit-thermometer, it is easily rectified by jerking the index down to the junction of the bulb and tube; then, by cautiously heating and cooling alternately the bulb, tube, and air-vessel at the top, the dis-united parts of the spirit may be distilled from place to place till the whole is collected into one column in union with that in the bulb.

When the steel index of the mercurial thermometer becomes immersed in the mercury, first cool the bulb (by evaporation of ether, if necessary) till the mercury is either fairly drawn below the index, or the column separates, leaving the index with mercury above it. Loosen the index by tapping, by a magnet, or by heating the tube, then apply heat to the bulb, and drive the index with its superincumbent mercury up into the air-vessel. When there, hold the instrument bulb downwards, and, suspending the index by a magnet, effect an union between the globule of mercury and the column below, by continuing to apply the heat till the latter rises into the air vessel. As the bulb cools, the whole mercury should descend in an unbroken column, after which the index may be restored to its place. Much patience and many trials are often required for success. An oil-lamp with a very small clear flame should be used.

Both the self-registering thermometers should be read off at the time of the 9 h. A.M. observation, as it is very improbable that the temperature at that hour should be such as to obliterate either record of the preceding 24 hours. Double maxima and minima, when they occur, if remarkable, should be recorded separately in a diary as supernumerary, and their accompanying circumstances should be noted.

The observer should be furnished with several other thermometers, all of sufficient delicacy to allow of estimating tenths of degrees, for observation of the temperature of the sea, or of the earth (when on shore), of falling rain, &c., and for a reserve in case of accident. All should be compared with the standard. That in habitual use for the sea temperature should be defended from accident in the act of immersion by a wire guard.

The thermometer for solar radiation should have its bulb blackened with a coat of Indian ink. It should be defended from currents of air by enclosure in a glass tube; and it would add infinitely to the value of a series of observations made with it if this tube were exhausted and hermetically sealed.* Its exposure to the sun should be perfectly free and full, and it should be suspended in free air, quite out of reach of any support or object heated by the sun's rays.

Hygrometers are of very various constructions, and depend on very different principles. That which has been recommended in preference to, and has almost universally superseded in practice every other,† consists of two thermometers, the bulb of the one being dry and of the other wet; being kept so by a covering of muslin, connected by a wet roll of cotton (lamp-wick) with a small cup of distilled or rain water placed close beneath it, so as to absorb and communicate water by capillary attraction. In frosts this arrangement is unavailing, and water must be poured on the muslin envelope, and allowed to freeze into a coat of ice, from which evaporation will still go on and depress the temperature, as if still liquid. They should be placed and observed in such locality as shall afford the best chance for procuring a fair indication of the moisture of the general atmosphere, and by no means in any confined or ill-ventilated situation between decks, where many persons habitually congregate, or which, from any other cause, is usually or periodically damp. The whole instrument should be protected with a cap of wirework to defend it from injury: this, if it interfere with the readings, should be removed a quarter of an hour before the observation. In reading the thermometers begin with the dry one, and use all the precautions recommended with respect to the "external" thermometer. Enter the simple readings, but at the head of each column place the zero *correction* (with its proper sign) required for its thermometer (a general rule for all thermometric entries), and leave a blank column for the "hygrometric depression," in calculating which subsequently the zeros must be *applied.* The reduction of the observations to derive the *elastic force of vapour at the dew-point* is effected by the formulæ of Dr. Apjohn:—

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* Such thermometers having their bulbs enclosed in an exhausted glass globe have been successfully made by Messrs. Negretti and Zambra, and are in use at the Royal Observatory of Greenwich, with the promise of very important results.—R. M.

† The hair hygrometer is delicate, exceedingly liable to derangement, and, unless prepared with extraordinary care, uncertain. Daniell's dew-point hygrometer, excellent in theory, is very costly on account of its great consumption of ether, and scarcely useable in hot climates, owing to the difficulty of preserving that liquid.

$$F = f - \frac{d}{88} \cdot \frac{h}{30} \; . \; . \; . \; . \; (a); \quad F = f - \frac{d}{96} \cdot \frac{h}{30} \; . \; . \; . \; . \; (b).$$

(*a*) to be used when the reading of the wet thermometer is above 32°, and (*b*) when below. In these, d is the hygrometric depression, h the height of the barometer, f the elastic force of vapour for the temperature shown by the *wet* thermometer, to be taken from Table III., Appendix, and F the elastic force of vapour at the dew-point, which (all the other quantities being known) these formulæ enable us to calculate. With F so calculated enter the same table under the column of Force of Vapour, and the corresponding *temperature* is the dew-point, which, however, is not wanted to be known except as a matter of curiosity.*

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* The discussion respecting the formulæ and coefficients of reduction of observations of this nature can hardly be regarded as satisfactorily terminated; and it cannot be denied that great difficulty still subsists in determining, by any mere reading of instruments, the exact hygrometric state of the air. In the absence of direct observation of the Dew Point, the actual absorption and weighing of the water contained in a given volume of air seems to be the only method free from

The Rain-Gauge.—This may be of very simple construction. A cubical box of tin or zinc, exactly ten inches by the side, open above, receives at an inch below its edge a square funnel, sloping to a small central hole. On one of the lateral edges of the box, close to the top of the cavity, is soldered a short pipe, in which a cork is *loosely* fitted; the whole should be well painted. The water which enters the reservoir through the funnel-hole is poured through the short tube into a cylindrical glass vessel graduated to cubic inches and fifths of cubic inches. Hence, one inch in depth of rain in the gauge will be measured by 100 inches of the graduated vessel, and a thousandth of an inch may easily be read off. It is very difficult to place the rain-gauge properly on shipboard, and its entries therefore require constant explanatory notes, pointing out causes tending to disturb its influence. In fact, excepting the mast-head (and there upon a gimbal), it seems hardly possible to devise a tolerably *permanent* situation for it. On land, a perfectly open exposure on the ground, or *very* little elevated above it, should be chosen. The quantity of water should be daily measured and registered at 9 A.M., unless the fall of rain be so heavy as to endanger filling the instrument within the 24 hours, when this operation should be performed as often as needed. Snow collected or water frozen in the reservoir should be melted.

The Anemometer.—Lind's would appear to be the only anemometer which can conveniently be used on shipboard. It is adjusted by filling it with water till the liquid in both legs of the syphon corresponds with zero of the scale. It is to be held perpendicularly with the mouth of the kneed tube turned towards the wind, and the amount of depression in the one leg and of elevation in the other is to be noted. The sum of the two is the height of the column of water which the pressure of the wind is able to support: and the

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theoretical objection, and it might not be very difficult to contrive a portable apparatus for this purpose.

[For all calculations relating to the humidity of the atmosphere, Glaisher's *Hygrometrical Tables* will be found very valuable.—R. M.]

force of the wind on a square foot is obtained from this height by Table IV. of the Appendix. In great degrees of cold a *saturated* brine may be used which does not freeze, and whose specific gravity being 1·244, the force given by the table must be multiplied by this factor. In addition to the regular hours of observation this instrument should be observed in storms, white squalls, or other circumstances of interest; the direction of the wind, as well as its force, should be registered at each observation; and for this it is well to have a small compass with a vane of card or thin and very moveable sheet *brass*, which may be fastened on the top of the anemometer, and which will indicate the direction in which its opening should be turned. In concluding the direction and the force of the wind from the vane and anemometer readings, a correction depending on the direction and velocity of the ship's motion is in strictness required. But such corrections are not *usually* applied, and it may be doubted whether the observations can be made accurately enough to render it worth while to apply them.*

The Actinometer.—This consists of a large hollow cylinder of glass, soldered at one end to a thermometer-tube, terminated at the upper end by a ball drawn out to a point, and broken off, so as to leave the end open. The other end of the cylinder is closed by a silver or silver-plated cap, cemented on it, and furnished with a screw, also of silver, passing through a collar of waxed leather, which is pressed into forcible contact with its thread, by a tightening screw of large diameter enclosing it, and working into the silver cap, and driven home by the aid of a strong steel key or wrench, which accompanies the instrument.

The axis of this screw is pierced to allow the stem of a spirit thermometer to pass out through it, the bulb (a very long one) being within the cylinder, to take the temperature of the enclosed liquid. The graduation is in the stem of the screw, which is prolonged to receive and defend it.

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* For a description of an improved form of Lind's anemometer by Sir W. Snow Harris, with a detailed explanation of its construction and mode of use, the reader is referred to *The Nautical Magazine* for March, 1858.—R. M.

The cylinder is filled with a deep blue liquid (ammonio-sulphate of copper); and the ball at the top being purposely left full of air, and the point closed with melted wax, it becomes, in any given position of the screw, a thermometer of great delicacy, capable of being read off on a divided scale attached. The cylinder is enclosed in a chamber blackened on three sides, and on the fourth, or face, defended from currents of air by a thick glass, removable at pleasure.

The action of the screw is to diminish or increase at pleasure the capacity of the hollow of the cylinder, and thus to drive, if necessary, a portion of the liquid up into the ball, which acts as a reservoir, or, if necessary, to draw back from the reservoir such a quantity as shall just fill it, leaving no bubble of air in the cylinder. The interior thermometer indicates approximately the temperature of the blue liquid for the subsequent reduction of the observation.

To use the instrument, examine first whether there be any air in the cylinder, which is easily seen by holding it level, and tilting it, when the air, if any, will be seen to run along it. If there be any, hold it upright in the left hand, and the air will ascend to the root of the thermometer-tube. Then, by alternate screwing and unscrewing the screw with the right hand, as the case may require, it will always be practicable to drive the air out of the cylinder into the ball, and suck down the liquid, if any, from the ball, to supply its place, till the air is entirely evacuated from the cylinder, and the latter, as well as the whole stem of the thermometer-tube, is full of the liquid in an unbroken column. Then, holding it horizontally, face upwards, slowly and cautiously unscrew the screw till the liquid retreats to the zero of the scale.

The upper bulb is drawn out into a fine tube, which is stopped with wax. When it is needed to empty, cleanse, and refill the instrument, liquid must be first forced up into the ball, so as to compress the air in it. On warming the end, the wax will be forced out, and the screw being then totally unscrewed, and the liquid poured out, the interior of the instrument may be washed with water slightly acidulated, and the tube, ball, &c., cleansed, in the same way, after which the wax must be replaced, and the instrument refilled.

To make an observation with the actinometer, the observer must station himself in the sunshine, or in some sharply terminated shadow, so that, without inconvenience, or materially altering his situation, or the exposure of the instrument in other respects, he can hold it at pleasure either in full sun or total shadow. If placed in the sun, he must provide himself with a screen of pasteboard or tin plate, large enough to shade the whole of the lower part or chamber of the instrument, which should be placed not less than two feet from the instrument, and should be removeable in an instant of time. The best station is a room with closed doors, before an open window, or under an opening in the roof into which the sun shines freely. Draughts of air should be prevented as much as possible. If the observations be made out of doors, shelter from gusts of wind, and freedom from all penumbral shadows, as of ropes, rigging, branches, &c., should be sought. Generally the more the observer is at his ease, with his watch and writing-table beside him, the better. He should have a watch or chronometer beating at least twice in a second, and provided with a seconds hand; also a pencil and paper, ruled according to the form subjoined, for registering the observations. Let him then grasp the instrument in his left hand, or, if he have a proper stand (which is preferable on shore or in a building *), otherwise firmly support it, so as to expose its face perpendicularly to the direct rays of the sun, as exactly as may be.

The liquid, as soon as exposed, will mount rapidly in the stem. It should be allowed to do so for a minute before the observation begins, taking care, however, by a proper use of the screw, not to let it mount into the bulb. At the same time the tube should be carefully cleared (by the same action) of all small broken portions of liquid remaining in it, which should all be drawn down into the bulb. When all is ready for observation, draw the liquid down to zero of its scale, gently and steadily; place it on its stand, with its screen before it, and proceed as follows, first reading off the internal thermometer.

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* This may consist of two deal boards, eighteen inches long, connected by a hinge, and kept at any required angle by an iron, pointed at each end. The upper should have a little rabate or moulding fitting loosely round the actinometer, to prevent its slipping off.

Having previously ascertained how many times (suppose 20) the watch beats in five seconds, let the screen be withdrawn at ten seconds before a complete minute shown by the watch, suppose at $2^h\ 14^m\ 50^s$. From 50^s to 55^s, say 0, 0, 0,.... at each beat of the watch, looking meanwhile to see that all is right. At 55^s complete, count 0, 1, 2,.... up to 20 beats, or to the whole minute, $2^h\ 15^m\ 0^s$, keeping the eye not on the watch, but on the end of the rising column of liquid. At the 20th beat read off, and register the reading ($12^{div.}\cdot 0$), as in column 3, A, of the annexed form. Then wait, watching the column of air above the liquid, to see that no blebs of liquid are in it, or at the opening of the upper bulb (which will cause the movement of the ascending column to be performed by starts), till the minute is nearly elapsed. At the 50th second begin to watch the liquid rising; at 55^s begin to count 0, 1, 2, up to 20 beats, as before, attentively watching the rise of the liquid; and at the 20th beat, or complete minute ($2^h\ 16^m\ 0^s$), read off, and instantly shade the instrument, or withdraw it *just out* of the sun and penumbra. Then register the reading off ($43^{div.}\cdot 3$) in column 3, B, and prepare for the shade observation. All this may be done without hurry in 20 seconds, with time also, if the end of the column be inconveniently high in the scale, to withdraw the screw, which is often required. At the 20th second prepare to observe; at the 25th begin to count beats, 0, 1, 2,....20; and at the 20th beat, *i.e.* at $2^h\ 16^m\ 30^s$, read off, and enter the reading in column 3, A, as the initial shade reading

($45^{\text{div.}}$·2). Then wait, as before, till nearly a minute has elapsed, and at 2^{h} 17^{m} 20^{s} again prepare. At 17^{m} 25^{s} begin to count beats; at 17^{m} 30^{s} read off, and enter this *terminal* shade reading ($42^{\text{div.}}$·8) in column 3, B, and, if needed, withdraw the zero.

Again wait 20^{s}, in which interval there is time for the entry, &c. At 17^{m} 50^{s} remove the screen, or expose the instrument in the sun; at 55^{s} begin to count beats; and at the complete minute, 18^{m} 0^{s}, read off ($14^{\text{div.}}$·8), and so on for several alternations, *taking care to begin and end each series with a sun observation*, and to read off the internal thermometer at the end of each set, or, if the observations be continuous, at every fifth sun observation. If the instrument be held in the hand, care should be taken not to change the inclination of its axis to the horizon between the readings, or the compressibility of the liquid by its own weight will produce a very perceptible amount of error.

1. Date and times of Observation. ——, 1850, Oct. 30.		2. Exposure, sun ⊙ or shade ×	3. Readings of the Instrument.		4. Change per Minute.	5. Internal Therm.	6.	Remarks.
Initial.	Terminal.		A. Initial.	B. Terminal.	B−A.			
h. m. s.	m. s.		div.	div.	div.	°		
2 15 0	16 0	⊙	+12·0	+43·3	+31·3			The times are reduced to *apparent* time, or to the sun's hour angle from the meridian. Zero withdrawn. Blackened Therm. 106°·3.
16 30	17 30	×	45·2	42·8	− 2·4			
18 0	19 0	⊙	14·8	48·2	+33·4			
19 30	20 30	×	28·0	26·8	− 1·2	75·5		
21 0	22 0	⊙	9·4	43·9	+34·5			
22 30	23 30	×	46·6	45·5	− 1·1			
24 0	25 0	⊙	9·0	43·2	+34·2			

In the annexed form column 1 contains the times, initial and terminal, of each sun and shade observation. Column 2 expresses by an appropriate mark, ⊙ and ×, the exposure, whether in sun or shade. Column 3 contains the readings, initial and terminal (A and B). Column 4 gives the values of B — A, with its algebraical sign, expressing the rise and fall per minute. And here it may be observed, that, if by forgetfulness the exact minute be passed, the reading off may be made at the next 10^s, and in that case the entry in column 4 must be not the *whole* amount of B — A, but only $\frac{6}{7}$ths of that amount, so as to reduce it to an interval of 60^s precise. Column 5 contains readings of the internal thermometer; column 6 is left blank for the results when reduced; and in column 7 are entered remarks, such as the state of the sky, wind, &c.; as also (when taken) the sun's altitude, barometer, thermometer, and other readings, &c.

A complete actinometer observation cannot consist of less than three sun and two shade observations intermediate; but five sun and four shade are much better. In a very clear sunny day it is highly desirable to continue the alternate observations for a long time, even from sunrise to sunset, so as to deduce by a graphical projection the law of diurnal increase and diminution of the solar radiation, which will thus readily become apparent, provided the *perfect* clearness of the sky continue—an indispensable condition in these observations, the slightest cloud or haze over the sun being at once marked by a diminution of resulting radiation. To detect such haze or cirrus, a brown glass applied before the eye is useful, and by the help of such a glass it may here be noticed that solar halos are very frequently to be seen when the glare of light is such as to allow nothing of the sort to be perceived by the unguarded eye.

When a series is long continued in a good sun, the instrument grows very hot,* and the rise of the liquid in the sun observation decreases, while the fall in the shade increases: nay, towards sunset it will fall even in the sun. This phenomenon (which is at first startling, and which seems to impeach the fidelity of the instrument) is, in fact, perfectly in order, and produces absolutely no irregularity in the resulting march of the radiation. Only it is necessary in the reduction of such observations to attend carefully to the algebraic signs of the differences in column 4.

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* It may become so hot as to hazard breaking the internal thermometer by surpassing the limit of its scale, or the boiling point of its spirit. Should the latter case be found to arise in practice, a coloured solution of muriate of lime might perhaps be advantageously substituted for alcohol.

Every series of actinometer observations should be accompanied with notices in the column of remarks of the state of the wind and sky generally, the approach of any cloud (as seen in the coloured glass) near to the sun; the barometer and thermometers, *dry* and *wet*, should especially be read off more than once during the series, if a long one, and, if kept up during several hours, hourly. The blackened thermometer for solar radiation should also be read off at the middle of every set, so as to accumulate a mass of comparative observations of the two instruments. The times should be correct to the nearest minute at least, as serving to calculate the sun's altitude; but if this be taken (to the nearest minute or two) with a pocket sextant, or even by a style and shadow, frequently (at intervals of an hour or less) when the sun is rising or setting, it will add much to the immediate interest of the observations. When the sun is near the horizon, its reflexion from the sea or any neighbouring water must be prevented from striking on the instrument; and similarly of snow in cold regions, or on great elevations in alpine countries.

Every actinometer should be provided with a spare glass, and all the glasses should be marked with a diamond; and it should always be noted at the head of the column of remarks which glass is used, as the co-efficient of reduction from the parts of the scale (which are arbitrary) to parts of the *unit of radiation* varies with the glass used.

To reduce provisionally a set of actinometer observations.—If the set consist of only four or five sun observations, with intermediate shades, take the mean of the "changes per minute" in column 4, for all the sun and for all the shade observations separately, attending duly to the signs. Change the sign of the latter mean, and add it to the former. The aggregate will be the uncorrected radiation in parts of the scale. To correct it for the unequal dilatability of the liquid, take the mean of the temperatures shown by the internal thermometer at the beginning and end of the set, and with it enter the table, Appendix, Table V., which contains the factor by which the uncorrected radiation is to be multiplied. If the series consist of more than a quadruple or sextuple observation, it must be broken into quadruplets or quintuplets, and each must be reduced separately as above.

The abstract unit of solar radiation to be adopted in the *ultimate* reduction of the actinometric observations is the *actine*, by which is understood that intensity of solar radiation which at a vertical incidence, and supposing it wholly absorbed, would suffice to melt one millionth part of a metre in thickness from the surface of a sheet of ice horizontally exposed to its action per minute of mean solar time; but it will be well to reserve the reduction of the radiations as expressed in parts of the scale to their values in terms of their unit until some future and final discussion of the observations.

Meanwhile no opportunities should be lost of *comparing* together the indications of different actinometers under similar and favourable circumstances, so as to establish a correspondence of scales, which in case of accident happening to one of the instruments will preserve its registered observations from loss. The comparison of two actinometers may be executed by one observer using alternately each of the two instruments, beginning and ending with the same; though it would be more conveniently done by two observers observing simultaneously at the same place, and each registering his own instrument. An hour or two thus devoted to comparisons in a calm clear day, and under easy circumstances, will in all cases be extremely well bestowed. In frosty or very cold weather the instrument should be exposed, for some time previous to commencing the observations, to the sun, which, by warming the liquid, increases its dilatability, which at low temperatures is inconveniently small.

Neither should each observer neglect to determine for himself the heat stopped by each of his glasses. This may be done also by alternating quadruplet observations made with the glass on and off, beginning and ending with the glass off, and (as in all cases) beginning and ending each quadruplet with a sun observation. For the purpose now in question a very *calm* day must be chosen, and a great many quadruplets must be taken in succession.

The actinometer is well calculated for measuring the defalcation of heat during any considerable eclipse of the sun. The observations should commence an hour at least before the eclipse begins, and be continued an hour beyond its termination, and the series should be uninterrupted, leaving to others the task of watching the phases of the eclipse. The atmospheric circumstances should be most carefully noted during the whole series.

Thermometers for Terrestrial Radiation.—The measure of terrestrial radiation is of no less importance to the science of meteorology than that of solar radiation, but no perfect instrument has yet been contrived for its determination. Valuable information, however, may be derived from the daily register of the minimum nocturnal temperature of a register spirit-thermometer, the bulb of which is placed in the focus of a concave metallic mirror, turned towards the clear aspect of the sky, and screened from currents. Such a thermometer may be read off and registered at the regular hours by day as well as by night, but it must be screened from sunshine, and a thermometer beside it also read off at the same times.

Registers.

To keep a meteorological register with due regularity, a skeleton form (No. 1) should be prepared, by ruling broad sheets of paper into columns destined for the reception of the daily and hourly entries in their *uncorrected* state, as read off or otherwise noted. This form may be most advantageously arranged in groups of columns, with general heading (*A*, *B*, *C*, &c.), and particular sub-headings (*a*, *b*, *c*, &c.), so as to class the entries in an order favourable to subsequent comparison and reduction. Thus the group *A* should carry the general heading *Date*; *B*, *Pressure*; *C*, *Temperature of air*; *D*, *Moisture*; *E*, *Radiation*; *F*, *Temperature of water*; *G*, *Wind*; *H*, *Cloud*; *I*, *Weather*; *K*, *Rain*; *L*, *Reference*; and opposite to every page ruled for entries should stand a blank page for remarks.

Under the general heading *A*, the sub-heading *Aa* will indicate the day of the month (marking the Sundays with S, and the days of new, full, and quarters of the moon with their appropriate marks ●, ☽, ○, ☾); and *Ab* will contain the hours of observation in each day, following the civil reckoning of time.

B will contain two sub-headings, *Ba*, *Bb*, corresponding to columns in which are entered respectively the readings of the barometer and its attached thermometer.

C will contain three: viz. *Ca* for entries of the external thermometer; *Cb*, the daily maxima; and *Cc*, the daily minima: placed opposite to the hours at which they are read off on the self-registering thermometer.

D will have two, *Da* and *Db*: viz. the readings of the dry and wet bulbs of the hygrometer.

Under *E* will stand three sub-columns, *Ea* for solar, and *Eb*, *Ec*, for terrestrial radiation. *Ea* will contain the readings of the black-bulb thermometer exposed in the exhausted tube to the sun at such of the regular hours when it can be observed; *Eb*, those of the thermometer exposed to clear sky in the metallic reflector; and *Ec*, those of a similar thermometer placed close beside it, and in all *other* respects similarly exposed. In these columns may also be entered the observed maxima of these elements, whether obtained by watching the instruments or by self-registering ones: and these observations should be distinguished from the others by enclosing them in parentheses, or by underlining them, &c.

F will contain the temperature of the surface-water under the first sub-heading, *Fa*; and under the second, *Fb*, that at two fathoms depth: the latter not being taken more than once a day, except when *Fa* indicates some sudden change.

G will contain the *direction* of the wind per vane and compass, in its first column, *Ga*; and its force, as read off on the anemometer, in *Gb*. If there be an upper and under current of wind, both their directions should be set down above and below a line, like a fraction.

H should have three sub-columns: viz. *Ha* for the amount of cloud in the region from the zenith down to 30° of altitude, and *Hb* for the amount below that altitude, each estimated in eighth parts of the whole respective areas of sky included in the two regions (*which are equal*), according to the best of the observer's judgment. *Hc* will contain the prevalent character of cloud, according to the nomenclature of Howard; denoting by C *cirrus*, by K *cumulus*,* by S *stratus*, and by N *nimbus*, by double letters their combination in transition from one to the other form (as *CS* cirro-stratus), and by letters with interposed commas (thus, *K*, *S*) the prevalence of one species of cloud in one and another in the other region. Two layers of cloud, one above the other, may be denoted by placing their characteristic letters above and below a line in the manner of a fraction. These forms of cloud are thus characterized:—*Cirrus* expresses a cloud resembling a lock of hair, or a feather, consisting of streaks, wisps, and fibres, vulgarly known as mares' tails. *Cumulus* denotes a cloud in dense convex heaps or rounded forms, definitely terminated above, indicating saturation in the upper clear region of the air, and a rising supply of vapour from below. *Stratus* is an extended continuous level sheet, which must not be confounded with the flat base of the *cumulus*, where it simply reposes on the vapour plane. The cumulo-stratus, or *anvil-shaped* cloud, is said to forerun heavy gales of wind.

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* To avoid the otherwise inevitable confusion of C and c in MS.

Peculiar aspects of cloud, preceding gales, squalls, or hurricanes, should be specially described in the sheet of remarks or in a journal. *Nimbus* is a dense cloud spreading out into a crown of cirrus above, and passing beneath into a shower.

Under the heading *I* will stand a note of the general state of the weather, according to Admiral Beaufort's system of abbreviations, which is as follows:—Numbers from 1 to 12 denote the force of the wind: thus 0 denotes *calm*; 1, *light air*, just perceptible; 2, *light breeze*, in which a ship, clean full, in smooth water, would go from one to two knots; 3, *gentle breeze* (from two to four knots); 4, *moderate breeze* (from four to six knots); 5, *fresh breeze*, in which a ship *could just carry* on a wind royals, &c.; 6, *stormy breeze* (single-reefed topsails and topgallant-sails); 7, *moderate gale* (double-reefed, &c.); 8, *fresh gale* (triple-reefed and courses); 9, *stormy gale* (close-reefed, &c.); 10, *whole gale* (close-reefed maintopsail and reefed foresail); 11, *storm* (storm-staysails); 12, *hurricane* (no canvas can stand). These numbers, in the absence of an anemometer, may be entered in column *Gb*. The following abbreviations denote the state of the weather:—

b.	*Blue sky*, be the atmosphere clear or heavy.
c.	*Clouds*. Detached passing clouds.
d.	*Drizzling* rain.
f.	*Foggy*.
g.	*Gloomy* dark weather.
h.	*Hail*.
l.	*Lightning*.
m.	*Misty* hazy atmosphere.
o.	*Overcast*. The whole sky covered with thick clouds.
p.	*Passing*, temporary showers.
q.	*Squally*.
r.	*Rain*. Continued rain.
s.	*Snow*.
t.	*Thunder*.
u.	*Ugly* threatening appearance.
v.	*Visibility* of objects; clear atmosphere.
w.	*Wet*. (Dew.)

o under any letter denotes a great degree.

K contains only a column, *Ka*, for the quantity of rain, melted snow or hail, collected in the rain-gauge at the regular hour. One entry a day will suffice, except in rains of unusual heaviness or in paroxysmal discharges, which will require special note. There will always be room in this column to note the temperature of the falling rain, if remarkable.

Finally, L is a small column at the edge of the page, containing merely *numbers of reference*, from 1 to the number of lines of entry in the page, to connect each entry with the *remarks* on it, or on any phenomenon which may have occurred in the interval since the last entry, which it will be probably necessary to enter on another sheet or interleaved page (carrying at its left-hand edge a similar reference column), or with any more extended notes which may form part of a diary such as every observant traveller or voyager ought to keep, and of which a summary for the month, so far as relates to meteorological subjects, should be appended to each monthly register.

Another skeleton form, No. II., should be prepared and ruled in corresponding columns, to receive the corrected and reduced results of the raw observations in Form I. This should have the column A, as in Form I.; B will consist of a single column, viz. the barometer, reduced to 32°; C, of the same number as in Form I., containing the *corrected* thermometer readings; under D will come two columns, Da and Db, of which the former will contain the *corrected* difference of the dry and wet bulb readings, and the latter the value of F, *the elastic force of vapour* at the dew-point by the formulæ already given. E and F will merely contain the *corrected* values of the corresponding entries in Form I.; and if there be anything in the remaining columns requiring correction or reduction, it will here, of course, be done; if not, those columns must be either carefully copied or simply referred to. In this form should be entered, *when needed*, the monthly means of the several columns (in calculating which care should be taken to verify the results by repetition); and it is recommended, before adding up the columns, to look down each to see that no obvious error of entry (as of an inch in the barometer, a very common error) may remain to vitiate the mean result. The precaution should also be taken of counting the *entries* in each column, so as to make no mistake in the divisor. The monthly maxima, minima, and ranges of the instruments should also be entered. Unless, however, the ship has been nearly stationary during the month, these calculations and their results are of little utility.

Both forms should be headed with the year and month on every page, and should bear the name of the ship and observer.

The observer will find it both interesting and instructive in a high degree to project the reduced observations (as fast as reduced, or monthly) of the barometric pressure, vapour tension (the value of *F* above mentioned), and temperature, in curves, by the aid of a paper of engraved squares, divided into inches and tenths by vertical and horizontal lines.* The comparison of the curves so projected in the case of the pressure and vapour tension is of especial interest, since there is reason to believe that the diurnal fluctuation of the barometer is partly, if not entirely, a hygrometric phenomenon arising from the superaddition of a variable hygrometric pressure to the otherwise uniform pressure of the *dry* atmosphere. The course of the barometric curve, too, will show far better than simple observation the chief maxima and minima which indicate the passage of the crests and troughs of atmospheric waves; and its continuance at a high or low level, or its gradual change, corresponding over long intervals of time with progressive changes of latitude and longitude, will enable the observer to trace out the limits of those deviations from the simple law of statical equilibrium which the researches of Schouw, Humboldt, and others have proved to exist more or less over the whole globe, and which those of Ermann in the Arctic, and King and Ross in the Antarctic regions, have shown to result in permanent local depressions to the enormous amount of a whole inch in the mercurial column.

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* Such papers may be obtained from Messrs. W. H. Allen and Co., Booksellers to the Honourable East India Company, No. 7, Leadenhall-street, London.

Occasional Observations.

There is much and most valuable matter for meteorological observation and remark which cannot find a place in the regular entries of a register, either from its occasional nature or from its statement requiring more detail than is consistent with the brevity of such entries. Observations of the Actinometer are of this kind, and require a separate register. Such also are all meteorological phenomena of a transitory nature, as hurricanes, thunderstorms, waterspouts, auroras, &c., of all which special and connected statements should be drawn up and entered in a diary (embodying all notes made at the time) as soon after their occurrence as possible, carefully noting all circumstances connecting them with the state of the atmosphere preceding and subsequent, and especially every precursory appearance or fact which may have left on the observer's mind the impression of a *prognostic*. Such also are those occasions of which the attentive observer will not fail to take advantage, when particular meteorological sequences of cause and effect stand out in unusual prominence, or when opportunity is offered for the exact or approximate determination of some *datum* of scientific interest. The following hints respecting observations coming under these descriptions will be worth attending to:—

Squalls, Storms, and Hurricanes or Cyclones.—It is hardly necessary to impress on the nautical observer the extreme importance of a minute attention to every adjunct of these formidable phenomena. From their first indications they should be attentively watched in all their phases, with a vigilance proportioned to their actual or expected intensity. Nothing in the way of *prognostic* should be left unnoticed. The "ugly threatening appearance" (*u*) should be analysed into its elements—atmospheric, celestial, oceanic, and (if in port) terrestrial signs of all kinds noted—such as the small white advancing cloud expanding into an arch, or the little white spot (*bull's-eye*) suddenly appearing in the zenith

—lurid sky—remarkable red colour of clouds and of other objects—bands of light and distant advancing walls of darkness—portions of cloud driven rapidly and irregularly—appearance of *ascending* lightning—peculiar aspect of stars or planets at night, or of the sun or moon at rising or setting, and *in what that peculiarity consists*—whirlwinds, waterspouts (and the direction in which they turn, whether ↶ or ↷), and peculiar veerings of wind with them, and alternations of calm—singular rises and lulls of wind and moaning or roaring noises, and whether these are *certainly* in the atmosphere—phosphorescent sea—flight of birds—uneasiness of animals—unusual abundance of certain fish. Meanwhile the movements of the barometer and the direction and force of the wind should be watched with unceasing vigilance. Hourly observations should be at once commenced, and the intervals diminished as it becomes more and more certain that a storm is in progress. When fairly established, the instruments cannot be read too frequently, and every sudden rise or fall of the one, every lull or *shift* of the other (as distinguished from *veering*, which is a *gradual* change of direction), should be noted *to the minute of its occurrence*, or rather the watch should be read and noted to the minute at every entry made.

During the continuance of the storm, and especially if there be reason (from its characters and its occurrence in the hurricane regions) to consider it as a revolving hurricane, or "cyclone," in the sense insisted on by Mr. Redfield, Colonel Reid, and Mr. Piddington, all the atmospheric appearances and changes should be noted as frequently as possible, particularly at changes of the wind and in the calm centre of the vortex, should this unfortunately reach the ship. Flashes of light appearing in the barometer tube (*not* simply arising from oscillation)—thunder and lightning, particularly at shifts of the wind, and their relation to sudden discharges of hail or rain—temperature of rain and of the sea—form and size of hailstones—whirlwinds or waterspouts occurring *in* the cyclone, their appearance, whirlings, tracks, size, &c.—circles of light overhead in the centre of the gale, to be estimated or measured as to their angular diameter—sun, moon, or stars if seen, and if of peculiar brilliancy or colours—state of the sea as to regularity, rising, falling, breaking, &c., particularly at the centre—veerings or oscillations of wind, and the exact intervals in which they occur—moderating of the wind for an hour or two or more after the gale has appeared to commence, and the state of the instruments and sky at the time. An exact account should be kept of the vessel's coming up or falling off, and the log hove, if possible, to ascertain with the utmost care the ship's drift in lying to. Blasts of hot and cold air—extraordinary light and darkness. Whenever partial clearing of the sky affords an opportunity, pay particular attention to the direction of the upper scud; at the going off of the gale the same attention to all the phenomena as at its coming on. Observations of barometer, &c., to be continued at gradually increasing intervals, and at length hourly till the usual state of things is fully restored—gradual rising of clouds at horizon or zenith and banks forming to be noted, and their altitudes measured. The precise position of the ship before and after the gale to be carefully indicated, and all possible information to be collected of the manner, exact times, &c., in which other ships have been affected by it, and every endeavour used to trace out the path of the centre, the diameter of the vortex, and the direction of its revolution, by subsequent inquiry whenever opportunity may occur.

Hurricanes, revolving storms, or "cyclones," according to the meteorologists above named (now fully established as true representations of fact), differ from mere local and temporary exaggerations of the regular atmospheric currents in this—that they are in the nature of vortices, or circulating movements participated in by masses of air of from 50 to 500 miles in diameter, revolving the more rapidly the nearer the centre, up to a certain distance, or radius, *within which there is a calm.* The place of this centre of rotation meanwhile advances steadily along a definite line upon the globe, with a velocity varying from 2 to 30 or 40 miles per hour, and pursuing a track which in some of the hurricane regions, as in the West Indies, has a singular fixity of geographical situation and geometrical form. But the character which it is of most importance to a seaman to know, and the knowledge of which may often save his ship from disaster, as ignorance of it has repeatedly been the cause of catastrophes which might have been avoided, is this, viz. that in the same hemisphere great cyclones *always* revolve *the same way* (so far, at least, as our present information extends), but that this direction is opposite in opposite hemispheres. In the northern hemisphere their rotation is *retrograde*, *i. e.* contrary to the motion of the hands of a watch laid face upwards, or in conformity with the motion of the hand in *unscrewing* a screw. In the southern their rotation is *direct*, conformable to the hands of a watch, or to the motion of the hand screwing *in* a screw into a horizontal board; and this general fact affords the following simple rule by which to know at any given moment *the bearing of the centre of the vortex*, which is the point of extreme danger, by reason of the fury of the wind in its vicinity, its sudden reversal, and the terrible sea which prevails there:—When *sure* that you are within the limits of a cyclone, stand erect and look full in the wind's eye; then, if in the northern hemisphere, turn yourself 90° or one quarter of the circle round *to your right* (if in the southern, as much to your left), and you will have the centre of the hurricane facing you. Thus, if in the northern hemisphere the wind at the ship be due north (or blow *from* the north), the centre bears due east from the ship's place.

The habitual tracks of hurricanes are but imperfectly known, and all which tends to throw light upon this part of the subject is of the utmost importance to navigation. The reader may consult the works of Mr. Redfield, Colonel Reid on the 'Law of Storms' (2nd edition), and 'The Sailor's Hornbook for the Law of Storms,' by Mr. Piddington, a work full of interest and information on the subject, and which no navigator should go to sea unprovided with. The direction of the wind *after* the complete passage of the hurricane is a point of interest, as indicating whether the "cyclone" consist in the bodily transfer of a given mass of rotating air, or in the successive transmission of a rotary movement from air to air *in situ*, the air in each point of its track being only transiently agitated.

Winds.—The points most important to remark respecting the wind are—

1st. Its average intensity and general direction during the several portions of the day devoted to observation.

2ndly. The hours of the day or night when it commences to blow after a calm, or subsides into one after a breeze.

3rdly. The hours at which any remarkable changes of its direction take place.

4thly. The course which it takes in veering, and the quarter in which it ultimately settles.

5thly. The usual course of *periodical winds*, or such as remarkably prevail during certain seasons, with the law of their diurnal progress, both as to direction and intensity—at what hours and by what degrees they commence, attain their maximum, and subside—and through what points of the compass they run in so doing.

6thly. The existence of crossing currents at different heights in the atmosphere, as indicated by the courses of the clouds in different strata.

7thly. The times of setting-in of remarkably hot or cold winds, the quarters from which they come, and their courses, as connected with the progressive changes in their temperature.

8thly. The connexion of rainy, cloudy, or fair weather with the quarter from which the wind blows, or has blown for some time previously.

Several of these points of inquiry have especial reference to land winds, and can only be duly studied in port or during residences on shore. In cruises along shore, or on arrival or departure, observe how far the influence of the land extends, and by what gradations the character of the winds changes from terrestrial to oceanic, especially with reference to the difference between the hours when the sun is above and when below the horizon.

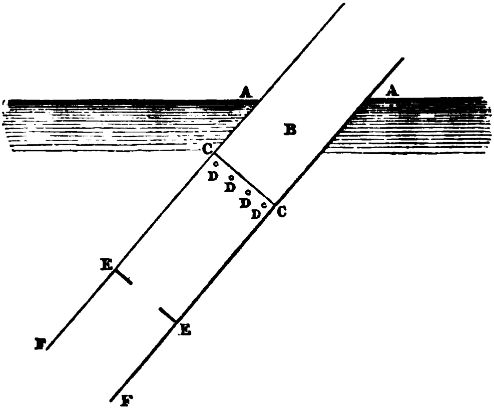
Clouds and Fogs.—The dissipation of cloud under the apparent influence of the full moon is a point to which attention has lately been called: the state of the sky on the days and nights of the full moon, and those immediately preceding and following it, should be noted with a view to confirming or refuting this connexion. Hourly observations, commencing before sunset, of the relative proportion of clear and clouded sky would be desirable.

The height of the vapour plane is a datum of importance, especially in tropical regions. At sea it is not easy to determine; but when near a mountainous coast, where the clouds repose at definite levels on the hills, many opportunities may occur of ascertaining it with precision. The lower level of unmelted snow may in such localities also be made a subject of inquiry. The average height of the vapour plane at sea under the equator is a meteorological element of much interest. Opportunities of determining it by measuring the apparent altitude of the flat bases of cumular clouds from two ships whose distance is known, or otherwise, should be seized when they offer.

When the sky suddenly clouds over, or when fogs form unexpectedly, the barometer and thermometer should be noted minutely, as such appearances often result from a rapid diminution of atmospheric pressure and consequent absorption of heat by the rarefaction of the air. Fogs prevailing at definite localities indicate a temperature of the sea habitually exceeding that of the air. They often also indicate the vicinity of ice. Whenever fogs are met with at sea, the temperature of the air and of the surface-water should be recorded with more than usual care.

Temperature of the Sea.—Shoals cast up water from a lower level to the surface where any current exists, and therefore a sudden change of temperature of the surface may indicate a shoal. In crossing currents coming from warmer or colder latitudes, the surface temperature should be especially attended to, and the maximum of irregularity due to the current watched for. Should opportunities offer of obtaining deep-sea temperatures, they should be eagerly seized.

Blue Colour of the Sea.—The cause of the blue colour of the sea and of deep or still lakes is still very imperfectly understood, and opportunities should be taken in calm weather to make observations which may tend to explain it. This may be done by an exploring-tube of the following simple character:—



A A is the water surface. B the tube. C C a glass to insure a perpendicular incidence of the visual ray. D, D, D, D, small air-holes to let air escape from the open subaqueous part of the tube F F. E E a diaphragm to cut off side-reflected light.

This is to be directed in all azimuths and inclinations to the horizon, in as still water as may be had, if only *very* deep and blue. The points to be observed are:—

1. The colour of the emergent light in all azimuths and inclinations.

2. Polarization, if any, when the water is very calm and the sun strong.

3. The possibility of directing a telescope down such a tube to examine the bottom.

4. The possibility of forming C C into an object-lens and converting the whole apparatus into a submarine telescope.

It is probable that the blue colour of the sky and of deep still water is referable to the same cause, and any observations tending to prove or disprove this would be valuable.

Observations in Port or in Temporary Residences on Shore.—Opportunities should not be lost of ascending lofty eminences, and noting thereon the hygrometric and thermometric conditions corresponding to altitudes measured by the portable barometer, or otherwise known.

The temperature of deep wells should be ascertained and that of the soil at different depths, which, if made with due care and under favourable circumstances, is an observation of very great interest. Excavations should be made in dry soil, and *under fair exposure to sun and wind*, in which should be buried, at depths of three, six, and nine feet, thermometers well wrapped in woollen cloth, or in pots of pounded charcoal, or even of dry sand, enclosed in strong vessels to defend them from damage, and to prevent the possibility of change of temperature in extracting and reading them. The zero points of the thermometers should be most scrupulously ascertained, and their errors *at* the temperatures registered made a subject of special inquiry. The readings should be exact to tenths of degrees. Observations thus made under the equator in various longitudes, *with scientific precision*, might furnish data of the utmost value towards determining the constancy or variability of the sun's radiation from year to year. If the thermometers cannot be spared, bottles of water similarly defended may be buried (or of brandy, if in frozen soil), and the temperature of the liquid taken immediately on raising them. In case of prolonged sojourn this should be repeated monthly.

Some localities are remarkable for enormous falls of rain. Thus it is stated, on the authority of Captain Roussin, that between the 1st and 24th of February, 1820, there fell *twelve feet seven inches* of rain in the Isle of Cayenne.* In all such localities great attention should be paid to the rain-gauge, and pains taken to procure extracts from perfectly authentic registers containing instances of the kind, and information respecting their attendant circumstances. In some geographical localities it is said never to cease raining—in others, that rain never falls. Local inquiry and consultation of records must here stand in lieu of personal observation, due care being taken to rely on none but unexceptionable evidence.

The phenomena of dew are of more interest, and can be better studied, on shore than at sea. The amount of dew collected by a given surface of any bibulous radiant, as cotton, &c., in clear nights, in exposures *perfectly* open to the sky, and on the level of the soil, should be registered. If accompanied with observations of the depression of the terrestrial radiant thermometer, and also of the hygrometer, such observations would acquire additional value.

The temperature of the soil under the direct influence of the sun, as indicated by a thermometer barely covered with dry earth, is an element of importance to the botanist, and may be recommended as an apt accompaniment to actinometric observations. The thermometer used should have a scale reading at least to 180° Fahr.

Meteorological registers, kept by persons of credit at places where the ship may remain or touch, should be inquired for and copied, or the originals procured; and the instruments with which the observations have been made should be carefully compared, and the height of their stations above the sea-level ascertained.

Waterspouts, Bull's-eye Squalls, Whirlwinds.—The transition from the mere eddy to the whirlwind, and from the whirlwind to the waterspout (*Trombe*), should be traced if possible. All circumstances from the first trace or prognostic to their final dissipation should be minutely noticed, especially the movements of the sea under their influence, and the direction of their rotation. At what distance is the whirling motion of the air perceptible? What are the indications of the barometer during their approach and recess? Do any and what electrical phenomena accompany them? Does the water really ascend along their axis, and to what height? Is the water which they discharge in "bursting" fresh or salt? Note its temperature.

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* Edinb. Phil. Journ., viii. 186, from Silliman's American Journal of Science, iv. p. 375.

Showers of Dust or Ashes.—When they fall, preserve specimens and examine them microscopically, whether consisting of organized or mineral matter. Note every circumstance, especially the direction of the wind, and whether an upper current, differing in direction from the lower, exist. The geographical situation of the ship especially should be exactly ascertained. Inquire for volcanic eruptions within a thousand miles of the place of their occurrence.

Thunderstorms, Lightning, Fireballs, &c.—Note the quarter of the horizon where distant lightning unaccompanied with thunder appears, and the extent which it embraces. Especially notice any appearance of forked lightning striking *upwards*. In an actual thunderstorm, especially attend to the quantity of rain or hail that falls—its intermittences, and its correspondence or the contrary with great bursts of lightning near at hand. Notice the apparent direction taken by the storm, with or against the wind. Attend to the remarkable reversal in the direction of the wind which often immediately follows the cessation of a thunderstorm. Violent thunder and lightning in the immediate vicinity of the place of observation sometimes, though *very* rarely, take place without rain, or with very little. In such cases, notice every particular with the utmost minuteness, and ascertain, if possible, whether the storm has been *elsewhere* attended with rain. Fireballs are stated to have been occasionally seen running along the surface of the sea, and so reaching, striking, and "bursting" on ships—appearances which have been supposed analogous to the electrical phenomenon termed *the glow discharge*. Attend to every circumstance which may favour or oppose this idea, especially the height of the clouds at the time, and whether or no they are remarkably depressed along the line taken by the fireball.

Should the ship be struck by lightning, if furnished with Sir Snow Harris's conductors (which appear to afford almost complete security against serious damage), examine the magnetism communicated to small steel bars (originally non-magnetic), fixed transversely across the copper conducting plates. Note any luminous appearance seen along the line of conduction. Immediately on the stroke, ascertain, by placing the hand on the conducting plate, whether it is in any degree heated. Notice peculiar noises, and endeavour to trace their origin, also the mode in which the lightning escapes from the ship, and the phenomena attending its escape.* If damage be done, describe minutely the sort of effects produced, and endeavour to trace the direction and character of the forces immediately productive of such as are purely mechanical.

Atmospheric Electricity can hardly be well studied at sea, the masts, sails, and rigging acting as perpetually interfering conductors. Indeed, it is said that, except in actual thunderstorms, no indications whatever of atmospheric electricity can be detected in the open ocean. This, however, should not be taken for granted. By going aloft the observer may put himself out of the reach of much of the interfering influence, taking with him an electroscope and a common jointed fishing-rod, having a glass stick well varnished with shellac substituted for its smallest joint to project into the atmosphere. To the end of the glass must be fixed a metallic rod terminating in a point, or carrying a small brass lantern, in which a lamp is burning, and connected with the electroscope by means of a fine copper wire. The electroscope may be either Saussure's pith ball, or Singer's gold leaf electrometer, and when charged the nature of the electricity may be tested by excited glass or sealing wax.

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* For the infinitely varied ways in which lightning may affect a ship when struck we recommend a perusal of Sir S. Harris's short but interesting work, 'Remarkable Instances of the Protection of certain Ships from the Destructive Effects of Lightning, &c.,' London, 1847.

Auroral Phenomena.—All such should be minutely registered, and all their phases, especially the formation, extent, situation, movement, and disappearance of arches, or any definite patches or banks of light. An acquaintance with the principal stars of the constellations is necessary to observe such phenomena with effect, and the observer will do well to provide himself for the purpose with planispheres, on which only the more conspicuous stars are indicated, with their allineations. The *exact* time (true at least to the nearest minute) of any such definite body of light being centrally on any known star should be observed, as a means (by the aid of corresponding observations) of determining its real situation and altitude. The slow drifting motion of such masses (in north latitudes generally southward—query if the reverse in south?) should be specially attended to. Pulsations, like waves of light, rushing up from the horizon, should be also particularly remarked, and any appearance of *patches of definite forms rendered visible by such pulsation as it traverses them*, but not otherwise appearing as luminous masses, particularly noticed. When arches or any considerable well-defined cloud-like masses are formed, mark on the chart their situation and extent among the stars at several noted epochs of time, particularizing the brightest portions; observe also the point of convergence of streamers and the formation of the corona, the central point or focus of which should be projected on the chart *with all possible exactness*, and the time of so doing exactly taken, so as to determine by subsequent calculation its altitude and azimuth. Any indication of the *near vicinity* of auroral phenomena, or of their existence at a level below that of ordinary clouds, should be most minutely investigated at the moment, and carefully and circumstantially recorded. The connexion, if any, between auroral masses and cirrous clouds should be traced if opportunity occur. Note also the meteors if remarkable within the auroral region.

Halos, parhelia, mock suns, and other luminous phenomena of the kind, should be noted, delineated with care if complicated, and their dimensions measured with a sextant or other instrument, by bringing the limb of the sun or moon (noting which limb) in contact with the two edges of the phenomenon in succession. Their colours also and their order should be described. Light cirro-stratus cloud in the neighbourhood of the sun has been observed to be bordered with three fringes of pink and green colours following the outline of the cloud. This rare and beautiful phenomenon if seen should be most particularly and carefully described. Perhaps in some climates it may be of not unfrequent occurrence. Unusual tints observed in the sky should be noted; and should that extremely rare phenomenon—the sun's disc appearing *of a pale blue colour*, so little luminous as to allow of being gazed at with impunity*—occur, the atmospheric circumstances should be carefully recorded.

The polarization of the light of the sky should be examined *habitually* with a polariscope, and the relation of the points of maximum polarization to the sun, and the observer's zenith, noticed in every variety of climate, and in various states of the sky, and anything apparently abnormal recorded.

Zodiacal light.—In the seasons of its appearance take every opportunity in tropical climates to ascertain with precision the place of its apex among the stars, its breadth and degree of brightness, and whether variable or not.

Meteors.—See Article I., Astronomy—Appendix I.

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* It occurred at Bermuda on the 12th and 13th of August, 1831, two days after the great Barbadoes hurricane of that year.

APPENDIX.

Table I.—Correction to be added to Barometric Readings for Capillary Action.

Diameter of Tube.	Correction for	
	Unboiled Tubes	Boiled Tubes.
Inch.	Inch.	Inch.
0·60	0·004	0·002
0·50	0·007	0·003
0·45	0·010	0·005
0·40	0·014	0·007
0·35	0·020	0·010
0·30	0·028	0·014
0·25	0·040	0·020
0·20	0·060	0·029
0·15	0·088	0·044
0·10	0·142	0·070

Table II.—Correction to be applied to Readings of Barometers with *Brass Scales* extending from the Cistern to the top of the Mercurial Column, to reduce the observation to 32° Fahrenheit.

Temp.	INCHES.															Temp.
	24·0	24·5	25·0	25·5	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
°	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	°
0	·061	·063	·064	·065	·067	·068	·069	·071	·072	·073	·074	·076	·077	·078	·080	0
1	·059	·061	·062	·063	·064	·065	·067	·068	·069	·071	·072	·073	·074	·076	·077	1
2	·057	·058	·060	·061	·062	·063	·064	·066	·067	·068	·069	·070	·072	·073	·074	2
3	·055	·056	·057	·059	·060	·061	·062	·063	·064	·065	·067	·068	·069	·070	·071	3
4	·053	·054	·055	·056	·057	·058	·059	·061	·062	·063	·064	·065	·066	·067	·068	4
5	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·065	·066	5
6	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	6
7	·046	·047	·048	·049	·050	·051	·052	·053	·054	·056	·056	·057	·056	·059	·060	7
8	·044	·045	·046	·047	·048	·049	·050	·051	·052	·053	·054	·064	·055	·056	·057	8
9	·042	·043	·044	·043	·046	·046	·047	·048	·049	·050	·051	·052	·053	·054	·054	9
10	·040	·041	·042	·042	·043	·044	·045	·046	·047	·047	·048	·049	·050	·051	·052	10
11	·038	·039	·039	·040	·041	·042	·042	·043	·044	·045	·046	·046	·047	·048	·049	11
12	·036	·036	·037	·038	·039	·039	·040	·041	·042	·042	·043	·044	·045	·045	·046	12
13	·033	·034	·035	·036	·036	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	13
14	·031	·032	·033	·033	·034	·035	·035	·036	·037	·037	·038	·038	·039	·040	·040	14
15	·029	·030	·030	·031	·032	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	15
16	·027	·028	·028	·029	·029	·030	·030	·031	·032	·032	·033	·033	·034	·034	·035	16
17	·025	·025	·026	·026	·027	·027	·028	·028	·029	·030	·030	·031	·031	·032	·032	17
18	·023	·023	·024	·024	·025	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	18
19	·021	·021	·021	·022	·022	·024	·023	·024	·024	·024	·025	·025	·026	·026	·027	19
20	·018	·019	·019	·020	·020	·020	·021	·021	·021	·022	·022	·023	·023	·023	·024	20
21	·016	·017	·017	·017	·018	·018	·018	·019	·019	·019	·020	·020	·020	·021	·021	21
22	·014	·014	·015	·015	·015	·016	·046	·016	·016	·017	·017	·017	·018	·018	·018	22
23	·012	·012	·012	·013	·013	·013	·013	·014	·014	·014	·014	·015	·015	·015	·015	23
24	·010	·010	·010	·010	·011	·011	·011	·011	·011	·012	·012	·012	·012	·012	·013	24
25	·008	·008	·008	·008	·008	·008	·009	·009	·009	·009	·009	·009	·009	·010	·010	25
26	·005	·006	·006	·006	·006	·006	·006	·006	·006	·006	·007	·007	·007	·007	·007	26
27	·003	·003	·003	·003	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	27
28	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	28
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
29	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	29
30	·003	·003	·003	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	30
31	·005	·006	·006	·006	·006	·006	·006	·006	·006	·006	·007	·007	·007	·007	·007	31
32	·008	·008	·008	·008	·008	·008	·008	·009	·009	·009	·009	·009	·009	·010	·010	32
33	·010	·010	·010	·010	·011	·011	·011	·011	·011	·012	·012	·012	·012	·012	·012	33
34	·012	·012	·012	·013	·013	·013	·013	·014	·014	·014	·014	·015	·015	·015	·015	34
35	·014	·014	·015	·015	·015	·015	·016	·016	·016	·017	·017	·017	·018	·018	·018	35
36	·016	·017	·017	·017	·017	·018	·018	·019	·019	·119	·020	·020	·020	·021	·021	36
37	·018	·019	·019	·019	·020	·020	·021	·021	·021	·022	·022	·022	·023	·023	·024	37
38	·020	·021	·021	·022	·022	·023	·023	·023	·024	·024	·025	·025	·026	·026	·026	38
39	·023	·023	·024	·024	·024	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	39
40	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	·030	·030	·031	·031	·032	40
41	·027	·027	·028	·029	·029	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	41
42	·029	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	·036	·036	·037	·037	42
43	·031	·032	·032	·033	·034	·034	·035	·036	·036	·037	·038	·038	·039	·040	·040	43
44	·033	·034	·035	·035	·036	·037	·037	·038	·039	·040	·040	·041	·042	·042	·043	44
45	·035	·036	·037	·038	·038	·039	·040	·041	·041	·042	·043	·044	·044	·045	·046	45
46	·038	·038	·039	·040	·041	·042	·042	·043	·044	·045	·045	·046	·047	·048	·049	46
47	·040	·041	·041	·042	·043	·044	·045	·046	·046	·047	·048	·049	·050	·051	·051	47
48	·042	·043	·044	·045	·045	·046	·047	·048	·049	·050	·051	·052	·052	·053	·054	48
49	·044	·045	·046	·047	·048	·049	·050	·050	·051	·052	·053	·054	·055	·036	·057	49
50	·046	·047	·048	·049	·050	·051	·052	·053	·034	·055	·056	·057	·058	·059	·060	50

TABLE II.—*continued.*

Temp.	INCHES.															Temp.
	24·0	24·5	25·0	25·5	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
°	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
51	·048	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	51
52	·050	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·064	·065	52
53	·053	·054	·055	·056	·057	·058	·059	·060	·061	·063	·064	·065	·066	·067	·068	53
54	·055	·056	·057	·058	·059	·060	·062	·063	·064	·065	·066	·067	·068	·070	·071	54
55	·057	·058	·059	·060	·062	·063	·064	·065	·066	·068	·069	·070	·071	·072	·073	55
56	·059	·060	·061	·063	·064	·065	·066	·068	·069	·070	·071	·073	·074	·075	·076	56
57	·061	·062	·064	·065	·066	·068	·069	·070	·071	·073	·074	·075	·076	·078	·079	57
58	·063	·065	·066	·067	·069	·070	·071	·073	·074	·075	·077	·078	·079	·081	·082	58
59	·065	·067	·068	·070	·071	·072	·074	·075	·076	·078	·079	·080	·082	·083	·085	59
60	·068	·069	·070	·072	·073	·075	·076	·077	·079	·080	·082	·083	·085	·086	·087	60
61	·070	·071	·073	·074	·075	·077	·078	·080	·081	·083	·084	·086	·087	·089	·090	61
62	·072	·073	·075	·076	·078	·079	·081	·082	·084	·085	·087	·088	·090	·091	·093	62
63	·074	·076	·077	·079	·080	·082	·083	·085	·086	·088	·089	·091	·093	·094	·096	63
64	·076	·078	·079	·081	·082	·084	·086	·087	·089	·090	·092	·094	·095	·097	·098	64
65	·078	·080	·082	·083	·086	·086	·088	·090	·091	·093	·095	·096	·098	·100	·101	65
66	·080	·082	·084	·085	·087	·089	·090	·092	·094	·096	·097	·099	·101	·102	·104	66
67	·083	·084	·086	·088	·089	·091	·093	·095	·096	·098	·100	·102	·103	·105	·107	67
68	·085	·086	·088	·090	·092	·094	·095	·097	·099	·101	·102	·104	·106	·108	·109	68
69	·087	·089	·090	·092	·094	·096	·098	·100	·101	·103	·105	·107	·109	·110	·112	69
70	·089	·091	·093	·095	·096	·098	·100	·102	·104	·106	·108	·109	·111	·113	·115	70
71	·091	·093	·095	·097	·099	·101	·102	·104	·106	·108	·110	·112	·114	·116	·118	71
72	·093	·095	·097	·099	·101	·103	·105	·107	·109	·111	·113	·115	·117	·119	·120	72
73	·095	·097	·099	·101	·103	·105	·107	·109	·111	·113	·115	·117	·119	·121	·123	73
74	·097	·099	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	·124	·126	74
75	·100	·102	·104	·106	·108	·110	·112	·114	·116	·119	·120	·122	·125	·127	·129	75
76	·102	·104	·106	·108	·110	·112	·114	·117	·119	·121	·123	·125	·127	·129	·131	76
77	·104	·106	·108	·110	·112	·115	·117	·119	·121	·123	·126	·128	·130	·132	·134	77
78	·106	·108	·110	·113	·115	·117	·119	·122	·124	·126	·128	·130	·133	·135	·137	78
79	·108	·110	·113	·115	·117	·119	·122	·124	·126	·128	·131	·133	·135	·137	·140	79
80	·110	·113	·115	·117	·119	·122	·124	·126	·129	·131	·133	·136	·138	·140	·143	80
81	·112	·115	·117	·119	·122	·124	·126	·129	·131	·134	·136	·138	·141	·143	·145	81
82	·114	·117	·119	·122	·124	·126	·129	·131	·134	·136	·138	·141	·143	·146	·148	82
83	·117	·119	·121	·124	·126	·129	·131	·134	·136	·139	·141	·143	·146	·149	·151	83
84	·119	·121	·124	·126	·129	·131	·134	·136	·139	·141	·144	·146	·149	·151	·154	84
85	·121	·123	·126	·128	·131	·133	·136	·139	·141	·144	·146	·149	·151	·154	·156	85
86	·123	·126	·128	·131	·133	·136	·138	·141	·144	·146	·149	·151	·154	·156	·159	86
87	·125	·128	·130	·133	·136	·138	·141	·143	·146	·149	·151	·154	·157	·159	·162	87
88	·127	·130	·133	·135	·138	·141	·143	·146	·149	·151	·154	·157	·159	·162	·165	88
89	·129	·132	·135	·137	·140	·143	·146	·148	·151	·154	·156	·159	·162	·165	·167	89
90	·131	·134	·137	·140	·142	·145	·148	·151	·153	·156	·159	·162	·164	·167	·170	90
91	·134	·136	·139	·142	·145	·148	·150	·153	·156	·159	·162	·165	·167	·170	·173	91
92	·136	·139	·141	·144	·147	·150	·153	·156	·158	·161	·164	·167	·170	·172	·175	92
93	·138	·141	·144	·147	·149	·152	·155	·158	·161	·164	·167	·170	·172	·175	·178	93
94	·140	·143	·146	·149	·152	·155	·157	·161	·163	·166	·169	·172	·175	·177	·180	94
95	·142	·145	·148	·151	·154	·157	·160	·163	·166	·169	·172	·175	·178	·180	·183	95
96	·144	·147	·150	·153	·156	·159	·162	·165	·168	·171	·174	·178	·181	·183	·186	96
97	·146	·149	·152	·156	·159	·162	·165	·168	·171	·174	·177	·180	·183	·186	·189	97
98	·148	·152	·155	·158	·161	·164	·167	·170	·173	·176	·179	·183	·186	·188	·191	98
99	·151	·154	·157	·160	·163	·166	·169	·173	·176	·179	·182	·185	·188	·191	·194	99
100	·153	·156	·159	·162	·165	·169	·172	·175	·178	·181	·184	·188	·191	·194	·197	100

TABLE III.—Elastic Force of Aqueous Vapour for every Degree of Temperature, from 0° to 103° Fahrenheit.

Temp. Fahr.	Force in Inches of Mercury.	Temp. Fahr.	Force in Inches of Mercury.	Temp. Fahr.	Force in Inches of Mercury.	Temp. Fahr.	Force in Inches of Mercury.
°		°		°		°	
0	0·051	26	0·147	52	0·389	78	0·942
1	0·053	27	0·153	53	0·402	79	0·973
2	0·056	28	0·159	54	0·417	80	1·005
3	0·058	29	0·165	55	0·432	81	1·036
4	0·060	30	0·172	56	0·447	82	1·072
5	0·063	31	0·179	57	0·463	83	1·106
6	0·066	32	0·186	58	0·480	84	1·142
7	0·069	33	0·193	59	0·497	85	1·179
8	0·071	34	0·200	60	0·514	86	1·217
9	0·074	35	0·208	61	0·532	87	1·256
10	0·078	36	0·216	62	0·551	88	1·296
11	0·081	37	0·224	63	0·570	89	1·337
12	0·084	38	0·233	64	0·590	90	1·380
13	0·088	39	0·242	65	0·611	91	1·423
14	0·092	40	0·251	66	0·632	92	1·468
15	0·095	41	0·260	67	0·654	93	1·514
16	0·099	42	0·270	68	0·676	94	1·562
17	0·103	43	0·280	69	0·699	95	1·610
18	0·107	44	0·291	70	0·723	96	1·660
19	0·112	45	0·302	71	0·748	97	1·712
20	0·116	46	0·313	72	0·773	98	1·764
21	0·121	47	0·324	73	0·799	99	1·819
22	0·126	48	0·336	74	0·826	100	1·874
23	0·131	49	0·349	75	0·854	101	1·931
24	0·136	50	0·361	76	0·882	102	1·990
25	0·142	51	0·375	77	0·911	103	2·050.

TABLE IV.—Showing the Force of the Wind on a square foot for different heights of the Column of Water in Lind's Wind-gauge.

Height of the Column of Water.	Force of the Wind in Avoirdupois Pounds.	Height of the Column of Water.	Force of the Wind in Avoirdupois Pounds.
Inches.		Inches.	
12	62·5	5	26·04
11	57·29	4	20·83
10	52·08	3	15·62
9	46·87	2	10·42
8	41·66	1	5·21
7	36·55	0·5	2·60
6	31·75	0·1	0·52
		0·05	0·26

Table V.—Showing the Factors by which the Results of Actinometer Observations have to be multiplied, to reduce them to a constant dilatability of the enclosed Blue Liquid, viz. that at 60° Fahr.

Internal Ther.	Reducing Factor.	Internal Ther.	Reducing Factor.	Internal Ther.	Reducing Factor.	Internal Ther.	Reducing Factor.
°		°		°		°	
30	2·888	63	0·943	96	0·642	129	0·550
31	2·713	64	0·925	97	0·638	130	0·549
32	2·562	65	0·908	98	0·634	131	0·547
33	2·430	66	0·892	99	0·630	132	0·545
34	2·312	67	0·877	100	0·626	133	0·543
35	2·205	68	0·862	101	0·622	134	0·541
36	2·106	69	0·849	102	0·618	135	0·540
37	2·014	70	0·837	103	0·615	136	0·538
38	1·930	71	0·826	104	0·612	137	0·536
39	1·853	72	0·815	105	0·609	138	0·535
40	1·781	73	0·805	106	0·606	139	0·533
41	1·715	74	0·795	107	0·603	140	0·532
42	1·654	75	0·785	108	0·600	141	0·530
43	1·597	76	0·775	109	0·597	142	0·528
44	1·543	77	0·766	110	0·594	143	0·527
45	1·492	78	0·757	111	0·591	144	0·525
46	1·443	79	0·748	112	0·588	145	0·524
47	1·397	80	0·739	113	0·586	146	0·522
48	1·353	81	0·731	114	0·583	147	0·521
49	1·312	82	0·723	115	0·581	148	0·519
50	1·274	83	0·716	116	0·578	149	0·518
51	1·239	84	0·709	117	0·576	150	0·517
52	1·206	85	0·702	118	0·573	151	0·515
53	1·175	86	0·695	119	0·571	152	0·514
54	1·147	87	0·689	120	0·569	153	0·513
55	1·120	88	0·683	121	0·566	154	0·512
56	1·094	89	0·677	122	0·564	155	0·511
57	1·069	90	0·671	123	0·562	156	0·509
58	1·045	91	0·666	124	0·560	157	0·508
59	1·022	92	0·661	125	0·558	158	0·507
60	1·000	93	0·656	126	0·556	159	0·506
61	0·980	94	0·651	127	0·554	160	0·505
62	0·961	95	0·646	128	0·552		

TABLE VI.—For determining Altitudes with the Barometer (from Baily's 'Astronomical Tables and Formulæ').

N.B. β, β' represent the heights of the barometer as read off at the *lower* and *upper* stations respectively in parts of any one scale.

t, t' the temperatures in degrees of Fahrenheit's thermometer, at the same respective stations, of the air, as shown by the detached thermometer.

τ, τ' the temperatures (also in degrees Fahrenheit) of the mercury at the same stations, as shown by the attached thermometer.

Thermometers in open air. Argument $= t + t'$.				Thermometers attached to the Barometer. Argument $= \tau - \tau'$.		Latitude of Place. Argument $= \phi$.	
$t+t'$	A.	$t+t'$	A.	$\tau-\tau'$	B.	ϕ	C.
°		°		°		°	
40	4·76891	102	4·79860	0	0·00000	0	0·00117
42	4·76989	104	4·79953	1	0·00004	5	0·00115
44	4·77089	106	4·80045	2	0·00009	10	0·00110
46	4·77187	108	4·80137	3	0·00013	15	0·00100
48	4·77286	110	4·80229	4	0·00017	20	0·00090
50	4·77383	112	4·80321	5	0·00022	25	0·00075
52	4·77482	114	4·80412	6	0·00026	30	0·00058
54	4·77579	116	4·80504	7	0·00030	35	0·00040
56	4·77677	118	4·80595	8	0·00035	40	0·00020
58	4·77774	120	4·80687	9	0·00039	45	0·00000
60	4·77871	122	4·80777	10	0·00043	50	9·99980
62	4·77968	124	4·80869	11	0·00048	55	9·99960
64	4·78065	126	4·80958	12	0·00052	60	9·99942
66	4·78161	128	4·81048	13	0·00056	65	9·99925
68	4·78257	130	4·81138	14	0·00061	70	9·99910
70	4·78353	132	4·81228	15	0·00065	75	9·99900
72	4·78449	134	4·81317	16	0·00069	80	9·99890
74	4·78544	136	4·81407	17	0·00074	85	9·99885
76	4·78640	138	4·81496	18	0·00078	90	9·99883
78	4·78735	140	4·81585	19	0·00083		
80	4·78830	142	4·81675	20	0·00087		
82	4·78925	144	4·81763	21	0·00091		
84	4·79019	146	4·81851	22	0·00096		
86	4·79113	148	4·81940	23	0·00100		
88	4·79207	150	4·82027	24	0·00104		
90	4·79301	152	4·82116	25	0·00109		
92	4·79395	154	4·82204	26	0·00113		
94	4·79488	156	4·82291	27	0·00117		
96	4·79582	158	4·82379	28	0·00122		
98	4·79675	160	4·82466	29	0·00126		
100	4·79768	162	4·82553	30	0·00130		

Take D equal to $\log.\beta - (\log.\beta' + B)$: then will the logarithm of the difference of altitudes in English feet be equal to $A + C + \log.\ D$.

Example:—In latitude 21° on the mountain of Guanaxato, in Mexico, Baron von Humboldt observed as follows:—

	Lower Station.	Upper Station.
Therm. in open air	$t = 77^\circ{\cdot}6$	$t' = 70^\circ{\cdot}4$
Therm. attached to barom.	$\tau = 77^\circ{\cdot}6$	$\tau' = 70^\circ{\cdot}4$
Barometer	$\beta = 30^{\text{in.}}{\cdot}05$	$\beta' = 23^{\text{in.}}{\cdot}66$

what was the difference of level between the stations?

$$\begin{array}{rlrl}
\text{Log } \beta' = & 1{\cdot}37401 & & \\
B = & 0{\cdot}00031 & & \\
\hline
 & 1{\cdot}37432 & & \\
\text{Log } \beta & 1{\cdot}47784 & & \\
\hline
D = & 0{\cdot}10352 & \log D = & 9{\cdot}01502 \\
 & & C = & 0{\cdot}00087 \\
 & & A = & 4{\cdot}81940 \\
\hline
 & & \text{Log } 6843{\cdot}7 \;= & 3{\cdot}83529
\end{array}$$

consequently the difference required = 6843·7 English feet.

ARTICLE VI.

SECOND DIVISION, SECTION 3.

ON ATMOSPHERIC WAVES AND BAROMETRIC CURVES.

BY WILLIAM RADCLIFF BIRT, ESQ. F.R.A.S.

(*Revised for this Edition.*)

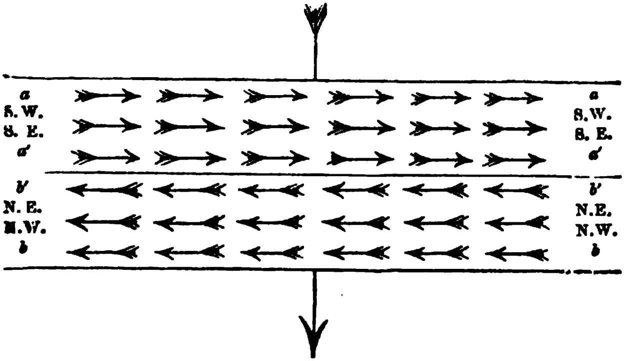
INTRODUCTION.

PROFESSOR DOVE, of Berlin, has suggested that in the temperate zones the compensating currents of the atmosphere, necessary to preserve its equilibrium, may be arranged as parallel currents on the *surface*, and not superposed or existing perpendicularly over each other, as in or near the torrid zone, and as illustrated by Lieutenant Maury in his 'Physical Geography of the Sea.' The views of Professor Dove may be thus ennunciated:—That in the parallels of Central Europe the N.E. current flowing towards the equator, to feed the ascending column of heated air, is not compensated by a current in the upper regions of the atmosphere flowing from the S.W., as in the border of the torrid zone, but there are also S.W. currents on each side the N.E., which, to the various countries over which they pass, appear as surface winds; in fact being disposed in alternate beds or layers S.W., N.E., as in figure 1.

The Professor also suggests that these parallel and oppositely directed winds are shifting, *i. e.* they gradually change their position with a lateral motion in the direction of the large arrow cutting them transversely.

In the course of the writer's researches on atmospheric waves he had an opportunity of testing the correctness of Professor Dove's suggestion, which he found to be in close accordance with the truth, for he not only ascertained the existence of the S.W. and N.E. compensating currents, but also that of another set of oppositely directed and compensating winds at right angles to them. These were N.W. and S.E., with a lateral motion towards the N.E. The writer also carefully discussed the barometric phenomena with relation to both these sets of currents, and arrived at conclusions which the reader will find in detail in the writer's third report presented to the British Association for the Advancement of Science (Reports, 1846, pp. 132 to 162), but which may be briefly enunciated as follows:—During the period which passed under the examination of the writer, he found the barometer generally rising with N.E. and N.W. winds, and that, as a maximum or *highest* reading of the mercury approached, the wind died away mostly to a calm. On the other hand, with S.W. and S.E. winds the barometer generally fell, the force of the wind proportionally increasing until the mercury passed its minimum or *lowest* reading.

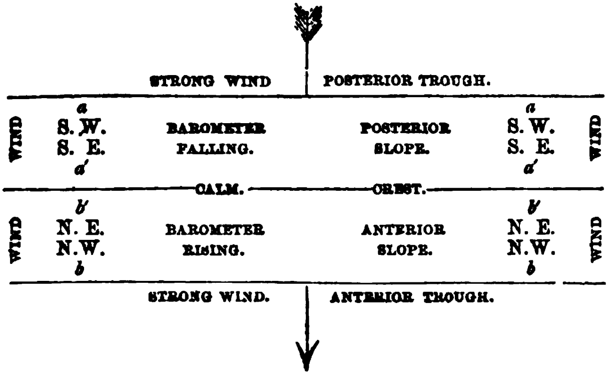
Fig. 1.



From these considerations it is clear that the phenomena may be thus illustrated:—Let the strata *a a a' a'*, *b' b' b b*, represent two parallel aërial currents or winds *a a a' a'* from S.W. or S.E., and *b' b' b b* from N.E. or N.W., and conceive them both to advance from the N.W. in the first instance, and from the S.W. in the second, in the direction of the large arrow. Now conceive the barometer to *commence* rising just as the edge *b b* passes any line of country, and to continue rising until the edge *b' b'* arrives at that line, when the maximum or *highest* reading is attained. It will be remarked that this rise is coincident with a N.E. or N.W. wind. The wind now changes and the barometer begins to fall, and continues to fall until the edge *a a* coincides with the line of country on which *b b* first impinged. During this process we have all the phenomena of an atmospheric wave; in fact the combined phenomena consisting of the two oppositely directed winds, their *decrease* and *increase* of force, accompanied by a *rising* and *falling* barometer, constitute in the true acceptation of the term an atmospheric wave; for when the edge *b b* passes a line of country the barometer is at a *minimum*. This minimum has been termed the *anterior trough*: it is characterised by a strong wind, often amounting in force to that of a hurricane. During the period the stratum *b' b' b b* transits, the barometer *rises*, while the wind *decreases* in force: this rise has been called the *anterior slope*. When the conterminous edges of the strata *a' a' b' b'* pass, a barometric *maximum* extends along the line of country formerly occupied by the anterior trough: this maximum has been designated the *crest*, and is marked by a *calm* state of the atmosphere, and accompanied by settled weather. During the transit of the stratum *a' a' a a*, the barometer *falls*, and the wind *increases* in force; this fall has been denominated the *posterior slope*. When the edge *a a* occupies the place of *b b*, the descent of the mercurial column is completed, another *minimum* extends in the direction of the former, and this minimum has been termed the posterior trough. Figure 2 illustrates the general phases of an atmospheric wave.

The localities in which atmospheric waves have hitherto been studied have been confined to the northern and central parts of Europe—the west of Ireland, Alten in the north of Europe, Lougan near the sea of Azov, and Geneva being the outlying points of the area over which they have been known to traverse. A most interesting instance of an atmospheric wave traversing Europe from the west of Ireland to the Black Sea is recorded in the French serial work, 'Cosmos;' and, in the 'Mercantile Marine Magazine' for May, 1856, we find a notice of the occurrence of an atmospheric wave in the Indian Ocean between 40° and 50° south latitude and 44° and 56° east longitude.

Fig. 2.



It will be remarked that the greatest portion of the European area is *inland*, but there is one important feature which the study of the barometer has brought to light, and which is by no means devoid of significance, viz. that its oscillations are much greater in the neighbourhood of *water*: thus it appears that the junction lines of land and water form by far the most important portions of the globe in which to study atmospheric waves, for in the great systems of European undulations it is well known that these oscillations increase *especially towards the north-west*, and the late Professor Daniel has shown from the Manheim Observations that small undulations having their origin on the northern borders of the Mediterranean have propagated themselves northward; and in this manner, but in a smaller degree, the waters of the Mediterranean have contributed to increase the oscillations of the barometer as well as the larger surface of the Northern Atlantic. From such considerations as these it becomes very desirable that our knowledge of the *rise* and *fall* of the BAROMETER, in immediate connexion with the *direction* and *force* of the WIND on the surfaces not only of our large oceans, but also on those of our inland seas, and especially in the neighbourhood of extensive archipelagoes, should be increased. In this respect captains and masters of vessels in her Majesty's and in the merchant service, lieutenants, surgeons, and midshipmen in the royal navy, and mates and inferior officers in the mercantile marine, may render essential service by observing and recording the state of the barometer, with the direction and force of the wind, several times in the course of the day and night;* and when it is considered that the immediate object in view is one in which the mariner is personally interested, and one in which his own safety is probably concerned, it is hoped that the keeping of a meteorological register having especial reference to the indications of the barometer, and the force and direction of the wind, will not be felt to be an irksome but rather an interesting occupation, the instruments standing in the place of faithful monitors, directing when and where to avoid danger, and the record furnishing important data whereby the knowledge of general laws may be arrived at, having an essential bearing on the interests both of her Majesty's service and the Mercantile marine.

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* By the officer of the watch being charged with this duty, and its being executed under his immediate superintendence, it is apprehended that a register may be kept with great regularity; indeed, such is the case in all vessels in which the captains observe in connexion with the Board of Trade, and we have now before us a three-hourly register of the indications of all the important meteorological instruments kept on board the 'Fair Rosamond,' the yacht of the Earl of Gifford, during a period of nearly three months.

OBSERVATIONS.

In sketching out a system of barometric observations having especial reference to the acquisition of data from which the *barometric character* of certain large areas of the surface of the globe may be determined, elucidatory of the immediate subject of this article, regard has been had to the distribution of land and water not only in the general sense, but as large areas are distinguished from each other; some, for instance, consisting of extensive spaces of the oceanic surface, unbroken, or scarcely broken, by land; others presenting a decidedly insular character, and the large masses of land exhibiting the same contrast of great continental and insular areas: especial regard has been paid to such oceanic, continental, and insular surfaces of our globe.

As these instructions are intended for officers in Her Majesty's navy and in the Mercantile marine, observations on land are scarcely alluded to; but in order that the data accumulated may possess that value which is essential for carrying on the inquiry in reference to atmospheric waves and barometric curves with success, provision is made to mark out more distinctly the barometric effects of the junction of large masses of land and water. It is well known that the oceanic surface, and even the smaller surfaces of inland seas, produce decided inflexions of the isothermal lines. They exercise an important influence on temperature. It has also been shown that the neighbourhood of water has a very considerable influence in increasing the oscillations of the mercurial column in the barometer; the nature of the great inland systems of European undulations has been, in a few instances, well studied, and the increase and decrease of oscillation in certain directions determined. The converse of this, however, so far as the writer is aware, has not yet been subjected to discussion, while there is now a systematic co-operation of observers, under the auspices of the Board of Trade, for the purpose of determining the meteorological affections of large masses of water, such as the central portion of the basin of the Northern Atlantic, the portion of oceanic surface between the Cape of Good Hope and Cape Horn, the Indian and Southern Oceans, and the vast basin of the Pacific. We are not aware that the observations now accumulating have been at all submitted to an examination capable of determining the nature of the barometric movements at sea, or exhibiting the progress of any one large atmospheric wave over the surface of an extensive ocean. Nor are we yet acquainted with the character of the oscillations, whether increasing or decreasing, as we recede from the central portions of the oceanic surfaces which we have mentioned towards the land which forms their eastern, western, or northern boundaries. The influence of the junction line of land and water, so far as it is yet known, has been kept in view in framing these instructions, and, as it appears so prominently in Europe, it is hoped that the weather-book containing the forms supplied by the Board of Trade will be fully filled up, especially when vessels are approaching the land. Upon such an extensive system of co-operation as that contemplated by the Board of Trade, and carried out to some extent by ships supplied with tested instruments and approved forms, combined with observations on land, a large space on the earth's surface, possessing peculiarities which distinguish it from others extremely unlike it in their general character, or assimilate it to such as possess with it many features in common, occupying more than two-thirds of a zone in the northern hemisphere, having a breadth of 40°, and including every possible variety of terrestrial and aqueous surface, from the burning sands of the great African desert, situated about the centre, to the narrow strip of land connecting the two Americas on the one side, and the chain of islands connecting China and Hindostan with Australia on the other, will receive considerable elucidation as to the distribution of wind—march of the barometer—propagation of atmospheric waves—direction and inflexion of isotherms or lines of equal temperature—heat of surface-water—soundings—indications of the thermometer at great depths—variations of the rainy, calm, and trade-wind belts, and many other meteorological phenomena that we cannot mention here. On each side of the African continent we have spaces of open sea between 30° and 40° west longitude north of the equator, and between 60° and 80° east longitude in or to the south of the equator, admirably suited for contrasting those meteorological affections before spoken of, as manifested in these spaces of open water, with those occurring in situations where the influence of the terrestrial surface comes into more active operation.

We shall specify below those localities from which careful observations would contribute greatly to increase our knowledge of atmospheric waves.

Northern Atlantic.—It appears from observations made in Western Europe that a *centre of great barometric disturbance* exists to the north-west of Scotland. All vessels nearing that locality may throw light on the greater oscillations of the barometer hereabout; and those engaged in the whale fisheries may contribute in no small degree to elucidate the extent of the barometric undulations and other meteorological phenomena in the neighbourhood of Baffin's Bay. Much important information may be gathered from vessels navigating Hudson's Bay, and also from the various stations of the Hudson's Bay Company, as well as from vessels plying on the great American lakes, and from stations around their shores. The seaboard of the United States should claim great attention, especially during the winter half-year.

Without doubt, the most interesting phenomenon, and one that lies at the root of all the great atmospheric movements, especially those proceeding northwards in the northern hemisphere and southwards in the southern, is the equatorial depression of the barometer, with its characteristic belt of calms, known by the expressive name of Doldrums. The equatorial depression was first noticed by the Baron von Humboldt, and confirmed by many observers since. We shall find the general expression of this most important meteorological fact in the Report of the Committee of Physics and Meteorology, appointed by the Royal Society in 1840, as follows:—"The barometer, at the level of the sea, does not indicate a mean atmospheric pressure of equal amount in all parts of the earth; but, on the contrary, the equatorial pressure is uniformly less in its mean amount than at and beyond the tropics." Vessels that are outward and homeward bound should, upon passing 40° north and 40° south latitude, observe the instruments with especial reference to the equatorial depression, so that the whole series of observations may include the minimum of the depression and the two maxima or apices forming its boundaries (see Daniell's 'Meteorological Essays,' 3rd edition), with the calms of Cancer and Capricorn, as deduced by Lieutenant Maury from the American observations. In passages across the equator, should the ships be delayed by calms, opportunities should be embraced for observing this depression with greater precision by means of *hourly* readings; and these readings will not only be valuable as respects the depression here spoken of, but will go far to indicate the character of any disturbance that may arise, and will point out, as nearly as such observations will allow, the precise time when such disturbance produced its effects in the neighbourhood of the ships. In point of fact, they will clearly illustrate the diversion of the tendency to rise, spoken of in the Report before alluded to, as resulting in ascending columns and sheets, between which wind-flaws, capricious in their direction and intensity, and often amounting to sharp squalls, mark out the course of their feeders and the indraft of cooler air from a distance to supply their void.*

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* In Admiral FitzRoy's letter to the President of the Board of Trade, inserted in the Report of the Meteorological Department, we have the following paragraph bearing especially on the state of the barometer within the tropics:—

"67. Within certain limits of latitude near the equator the barometer varies so little from a normal height now ascertained, that, allowing for its tidal change, any ship between those parallels may ascertain the error of her barometer, aneroid or sympiesometer, to nearly three

Hourly observations, or, at all events, those provided for by the Board of Trade, should be made off the Western Coast of Africa, having especial reference to this depression, also to the elucidation of the origin of the great system of southwesterly atmospheric waves that traverse Europe. They should also furnish data for comparison with the amount of oscillation and other barometric phenomena in the Gulf of Mexico and the Caribbean Sea, a portion of the torrid zone essentially different in its configuration and in the relations of its area to land and water, as contradistinguished from the northern portion of the African continent. Such observations are the more desirable as the vessels may approach the land, and should be carefully made in both localities, viz. off the continent of Africa and amongst the West Indian islands.

Southern Atlantic.—There are two points in the southern hemisphere, between 80° west longitude and 30° east longitude, that claim particular attention in a barometric point of view—viz. Cape Horn and the Cape of Good Hope. Too much attention cannot be paid to the indications of the barometer, combined with the *direction* and *force* of the wind, as vessels are approaching or leaving the Cape of Good Hope, especially for contrasting the meteorology of the southern extremity of Africa with the northern part of the South Atlantic Ocean, which has been termed the *true Pacific Ocean of the world.* At St. Helena a gale is scarcely ever known; it is also said to be entirely free from actual storms (Col. Reid's 'Law of Storms,' 1st edition, p. 415). It may therefore be expected that the barometer will present in this locality but a small oscillation, and ships in sailing from the Cape to St. Helena will do well to ascertain the decrease of oscillation as they approach that island. The same thing will hold good with regard to Cape Horn: it appears, from previous observation, that a permanent barometric depression exists in this locality, most probably

hundredths of an inch, and this without incurring risk by moving the instrument, and without any trouble beyond making the usual observations."

in some way connected with the immense depression noticed by Captain Sir James Clark Ross, towards the Antarctic Circle. The general character of the atmosphere off Cape Horn is also extremely different from its character at St. Helena. It would, therefore, be well for vessels sailing into the Pacific by Cape Horn to adhere as closely as possible to the instructions issued by the Board of Trade.

Before quitting the Atlantic Ocean it may be well to notice the marine stations mentioned in my Third Report on Atmospheric Waves,* as being particularly suitable for testing the views advanced in that report, and for tracing a wave of the south-westerly system from the most western point of Africa to the extreme north of Europe. A series of hourly observations off the western coast of Africa has already been suggested. Vessels staying at Cape Verde Islands should not omit to make observations at two hours' interval *during the whole of their stay*, and, when circumstances will allow, to make them hourly. At the Canaries, Madeiras, and the Azores, similar observations should be made. Vessels touching at Cape Cantin, Tangier, Gibraltar, Cadiz, Lisbon, Oporto, Corunna, and Brest, should also make these observations while they are in the localities of these ports. At the Scilly Isles we have six-hourly observations, made under the superintendence of the Honourable the Corporation of the Trinity House. Ships, in nearing these islands, and making the observations already pointed out, will greatly assist in determining the increase of oscillation proceeding westward from the nodal point † of the two great European systems. Vessels navigating the North Sea, the Baltic, and the coast of Norway, as far as Hammerfest, may greatly contribute towards the same object; nor is the Mediterranean without considerable interest, both as regards these particular waves and the influence which its waters exert in modifying the two great systems of central Europe. We have already alluded to the influence of its waters in *originating* small atmospheric waves, and no opportunity should be lost for increasing our knowledge of its meteorology, especially in the Straits of Gibraltar, the neighbourhood of Sicily and Italy, and in the Grecian Archipelago.

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* Reports of the British Association for the Advancement of Science, 1846, p. 139.

† Nodal point. The two systems of north-east and north-west winds, with their compensatory south-west and south-east winds, as explained on pp. 171, 172, very materially influence the barometer, so that in the neighbourhood of Brussels, for instance, the variations of pressure as manifested by the instrument are very much less than in localities removed from that city towards the *north-west*. Those points on the terrestrial or oceanic surfaces where the oscillations of the mercury are smaller than in the localities around them are called *nodal points*.

The Indian and Southern Oceans.—There is perhaps no portion of the aqueous surface of the globe with the meteorological character of which we are better acquainted than the Indian Ocean, traversed as it is by vessels trading to our Indian territories, the empire of China, and our flourishing colonies in Australia; its regions of trade-winds and monsoons, its calms and variables, its rains and storms, have been tolerably well marked out. Still much remains to be done, and the example so well set forth in the very bosom of the Indian Ocean itself—(in that island gem which rises above its waters and stands as a friendly resting-place between the Cape, stormy as it is at times, and the Bay over which the revolving cyclone sweeps with devastating violence, or that sea in which the typhoon stalks abroad, spreading around and within its circumference destruction and death)—an example, likely to be attended with results of almost incalculable benefit to seamen—should be most assiduously followed, especially in that locality the winds and storms of which have contributed in no small degree to develope to a greater extent that peculiar power of the human mind which seeks to apprehend at a glance the varied and complicated dispositions of natural phenomena spread over an extensive surface, and to grasp that thread of relationship which binds the whole together, and shows that each is but a part of one mighty and stupendous whole.

These reflections have been forced upon us by the consideration of Professor Meldrum's paper on the Meteorology of the Indian Ocean. It forms one of the Meteorological papers issued by the Board of Trade, and should be in the hands of every commander who sails eastward of the Cape. The portion more particularly interesting to us in connexion with this article is that which treats of the N.E. wind eastward of the Cape, and the S.W. wind which blows between it and the Cape. If our readers will take the trouble to compare Professor Meldrum's arrows indicating these winds on his chart with our diagram of an atmospheric wave, they will at once see that the winds in question form a well-marked instance of a wave rolling from the eastern coasts of Africa to about 70° E. long., on which meridian it is generally broken up. The elements of the wave appear to be unmistakeable; but, as the phenomena of the cyclone are reversed in the opposite hemispheres, so are those of the wave. In the northern hemisphere, the barometer, during the passage of an atmospheric wave, *rises* with N.E. winds; *in this instance*, in the southern hemisphere, it *falls;* in the northern hemisphere, as the N.E. winds pass they *decrease* in force; in the southern hemisphere they appear *to increase;* and it is highly probable that, as over so large an area as 50° of E. long. and 20° of S. lat. these waves appear continually to roll, so the phenomena exhibited will be exactly the opposite of those characterising the atmospheric waves of western Europe. The area above marked out, viz. from 20° to 70° E. long., and from 20° to 40° S. lat., will consequently claim great attention while sailing through it.

A highly practical question, however, arises here. Professor Meldrum shows that at the Mauritius, lat. 20° 10′ S., long. 57° 29′ E., on the 6th of March, 1853, the barometer was low, 29$^{\text{in}}$·738, and *falling*, with wind at E.S.E. On the 7th it fell calm, while at the same time the 'Fanny Fisher,' in 25° 22′ S. lat., 80° 57′ E. long., had fresh breezes from E.S.E.; her barometer, which had been falling, was quoted at 29$^{\text{in}}$·82, and she took in a single reef of her topsails. On the 8th, in 24° 10′ S. lat., 77° 17′ E. long., she experienced a fresh gale between E. and E.S.E.; was reduced to close-reefed topsails; hove-to, on the port tack, gale increasing and barometer falling ($29^{in}\cdot40$). On the 9th, a heavy gale, with constant wind E.N.E., barometer rising rapidly. At noon her position was 24° 59′ S. lat., 76° 39′ E. long.

From these quotations it would appear that a circular storm had passed to the *northward* of the ship. Professor Meldrum finds, however, that the bad weather is not to the northward, but to the *westward*, and he thus reasons that while a captain, implicitly relying on the instructions of cyclonologists, would endeavour to pass in front of the storm, and steer W. or W.N.W., by so doing he would get the worst of it, and steer into instead of away from the storm: in fact, he would run into the very heart of the gale. If, then, the phenomena of the storms and waves are, on the one hand, identical, while, on the other, the fury of the cyclone is raging in one direction and that of the atmospheric wave in the *opposite* or nearly so, what criterion has the commander to guide him in the determination that his gallant vessel is ploughing through the sea raised by the winds of the atmospheric wave, and not battling with that in the dangerous quadrant of a cyclone?

This is an important question, and one that must be answered before a commander can find himself perfectly at ease in the Indian Ocean anywhere eastward of the Cape and southward of Madagascar and the Mauritius. Hereabout cyclones generally move towards the S.E. Professor Meldrum considers that they are generated between the N.E. and S.W. winds, *i. e.* in the *trough* between the two compensating winds. If so, there would be *two* classes of phenomena that would at once decide the question. With a N.E. wind, a cyclone approaching from *north-west*, and catching the ship on the southern quadrant, the wind would veer to E., increase in force, veer to S.E., and pass off at S.; but if the ship were caught on the eastern quadrant, the wind would veer to N., increase in force, then veer to N.W., and pass off at W. All this is very different from S.E., E., to N.E. veering. It would be indeed but rarely that between 20° and 30° S. lat. and 50° and 70° E. long. cyclones would bear down from N.E.; a few might between 20° and 30° S. lat., and here the veering from S.E. by E. to N.E. might indicate the passage of the storm to the northward, but generally in higher latitudes than 23° S.; in these localities cyclones *re-curve*, moving to S. and S.E. A case, therefore, of veering from S.E. by E. to N.E. in latitudes higher than 23° S. would be regarded by the commander as very *suspicious*, and he would look out for his bad weather to the W. and S.W., rather than to the N. and N.E.

But what is a commander to do to avoid the fury of an atmospheric wave, should it become inconveniently strong? In the Journal compiled by Professor Meldrum, the strongest wind recorded in either section of the wave—*i. e.* N.E. or S.W.—is 9, or a close-reefed topsail gale, which is equal to a pressure of 23 lbs. on the square foot, as determined by Mr. Morton at the Cape of Good Hope; the mean strength of the N.E. being 5·2, or a moderate fresh breeze, with a pressure of 8 lbs., while that of the S.W. is 4·8, or very nearly the same. The commander has clearly not the chance of manœuvring, as, in a revolving storm, the wind appears to be *straight lined*, and each section of considerable length. If his course be westward, he may be every moment approaching the *trough*, where the wind is *strongest;* how to avoid it does not clearly appear. With such winds his best course seems to be to make himself as snug as possible, to prepare for the *strongest* wind *on record* in these localities, and to keep a sharp look-out for the *change*. If a rotatory storm come rolling on between the N.E. and S.W. winds, so much the better, provided it does not exceed the *strongest wind of the wave*, especially if he be caught on the southern quadrant, for his ship will then be carried by the winds of the southern border into the S.W. stream; but if he be caught on the eastern quadrant, then he is soon headed off his course, and must round-to while the westerly winds pass over him; they will quickly be followed by the S.W. stream.

It would appear that when the 'Fanny Fisher' fell in with the gales above alluded to she was considerably to the eastward of the locality in which cyclones recurve, viz. a space of 10° square, comprised between 20° to 30° S. lat., and 55° to 65° E. long. It is exceedingly unlikely that 15° east of this locality a cyclone should bear down upon a ship from N.E., or its centre pass a little to the northward of it.

Since the preceding paragraphs were written, the writer has most carefully examined Professor Meldrum's paper, and finds not only the general north-east and south-west winds, as laid down in the charts, accompanying it, but some remarkable curvilinear movements, as indicated in fig. 3, not noticed by the Professor. The space devoted to this article precludes further remarks here, with the exception that, in the larger segment of the diagram, the wind is seen as blowing in a contrary direction to that indicated by the 'Law of Storms.' In fact it is, so far as the writer is aware, a new phenomenon, and will make the third kind of anemonal movement with which we are now acquainted: the atmospheric wave of Dove, illustrated in figs. 1 and 2; the rotatory storm of Redfield and Reid, illustrated in figs. 4 and 6; and the cyclonic converging segments as illustrated in figs. 3 and 5.

Fig. 3.

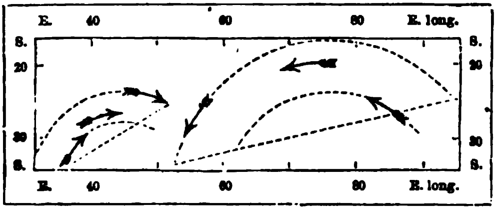


Fig. 4.

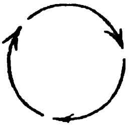


Fig. 5.

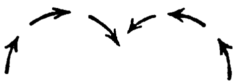
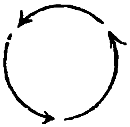


Fig. 6.



The Pacific Ocean.—Our knowledge of the meteorology of the Pacific is at present so small, especially when compared with that of the Atlantic and Indian Oceans, that we cannot do better than to request that all masters of vessels will co-operate, while sailing over any of its waters, in duly filling up the spaces in the weather-book.

In the previous sketch of the localities for the more important observations, it will be seen that within the tropics there are three which demand the greatest regard.

I. The Archipelago between the two Americas, more particularly comprised within the 40th and 120th meridians west longitude, and the equator and the 40th degree of north latitude. As a general principle, we should say that vessels within this area should observe the barometer at every hour appointed by the Board of Trade. Its eastern portion includes the lower branches of the storm paths, and on this account is peculiarly interesting, especially in a barometric point of view.

II. *The Northern portion of the African Continent, including the Sahara or Great Desert.*—This vast radiating surface must exert considerable influence on the waters on each side northern Africa. Vessels sailing within the area comprised between 40° west and 70° east and the equator and 40th parallel, should also make observations at the same hours.

III. *The great Eastern Archipelago.*—This presents a somewhat similar character to the western; like that, it is the region of terrific hurricanes, and it becomes a most interesting object to determine its barometric phenomena; the system of observation appointed by the Board of Trade may therefore be resorted to within an area comprised between the 70th and 140th meridians, and the equator and the 40th degree of north latitude.

The southern hemisphere also presents three important localities, the prolongations of the three tropical areas. It is unnecessary to enlarge upon these, as ample instructions have been already given. We may, however, remark, with regard to Australia, that the observations above recommended should be made within the area comprised between the 100th and 190th meridians east, and the equator and the 50th parallel south, and hourly ones in the immediate neighbourhood of all its coasts.

EXTRA OBSERVATIONS.

In reference to certain desiderata that have presented themselves in the course of my researches on this subject (see Report of the British Association for the Advancement of Science, 1846, p. 163), the *phases* of the larger barometric undulations, and the *types* of the various seasons of the year, demand particular attention and call for extra observations at certain seasons: of these, three only have yet been ascertained—the type for the middle of November, the annual depression on or about the 28th of November, and the annual elevation on or about the 25th of December. The enunciation of the first, in reference to London and the south-east of England, is as under: "That during fourteen days in November, more or less equally disposed about the middle of the month, the oscillations of the barometer exhibit a remarkably symmetrical character, that is to say, the fall succeeding the transit of the maximum or the highest reading is to a great extent similar to the preceding rise. This rise and fall is not continuous or unbroken; in some cases it consists of *five*, in others of *three*, distinct elevations. The complete rise and fall has been termed the great symmetrical barometric wave of November. At its setting in, the barometer is generally low, sometimes below twenty-nine inches in the western part of Europe, especially in the neighbourhood of Ireland. This depression is generally succeeded by *two* well-marked undulations, varying from one to two days in duration. The central undulation, which also forms the apex of the great wave, is of larger extent, occupying from three to five days; when this has passed, two smaller undulations corresponding to those at the commencement of the wave make their appearance, and at the close of the last the wave terminates." With very slight exceptions, the observations of several years have confirmed the general correctness of this type.

The symmetrical wave has been observed in Dublin; its progression has been ascertained in a south-easterly direction as far as Munich, and M. Lais has traced similar barometric movements in November, 1854, from the Bristol Channel to the Black Sea. In the autumn of 1856 it passed over Portugal, Spain, and the eastern portion of the Mediterranean, as appears from the log of Lord Gifford's yacht the 'Fair Rosamond.' The close or termination of the great November wave is mostly *stormy*. Mr. Milne alludes to the close of November as being generally a stormy period, and we find, from the 'Fair Rosamond's' log, that similar weather occurred in the Mediterranean during the last week of the month in 1856. It would be well if logs in every respect similar to that kept by Lord Gifford were numerous. Masters of vessels sailing on the Atlantic between 30° and 60° N. latitude and the meridian of Greenwich and 40° W. longitude, would do well to keep such. We cannot speak too highly of the value of the one before us, and we hope that so good an example will be extensively followed, not only over the area above specified, but also in the North Sea; off the coasts of France, Spain, Portugal, and the northern parts of Africa; and in the Mediterranean.

It is highly probable that movements of a somewhat similar character exist in the southern hemisphere. The November wave is generally preceded by a high barometer and succeeded by a low one, and this low state of the barometer is always accompanied by stormy weather. We are therefore prepared to seek for similar phenomena in the southern hemisphere, in those localities which present similar states of weather, such as the Cape of Good Hope and Cape Horn, and at seasons when such weather predominates. At present we know but little of such barometric movements as are above specified in the southern hemisphere, and every addition to our knowledge in this respect will open the way to more important conclusions.

In closing this article the writer begs to acknowledge the obligations he is under to Admiral FitzRoy for the assistance which that officer has rendered him during its revision for the present edition of the 'Manual,' and to present his best thanks for the information which the Admiral has so readily placed at his disposal.

ARTICLE VII.

THIRD DIVISION, SECTION 1.

GEOGRAPHY.

BY W. J. HAMILTON, ESQ., PRES. R.G.S., 1848–49.

IN drawing up the following remarks for the use of those requiring information as to the principal points to which, in respect of geographical investigations, their attention should be mainly directed, the first thing which strikes us is the rapid progress which has been made of late years in the study of the science of geography. Nor, when we consider the nature of the subject, and our own national position, with our colonies extending to every quarter of the globe, our ships navigating every sea, and our travellers exploring every country, is there any reason to be surprised at such a result. The evidence of this progress will be found in the more scientific nature of the observations made, and in the increasing number of valuable maps which are constantly, and in all countries, being brought under the notice of the public.

It must, however, be admitted, that we are yet very far from possessing accurate maps of many very important regions—all the north of Scotland even being still inaccurately represented on any map. But even when we shall have attained such ends, we shall be but at the commencement of our science. The most perfect maps are but the skeleton or groundwork of geography, taken in the higher and more extended sense in which it should be cultivated. Its application to the progress and development of civilization, and to the knowledge of the animal and vegetable productions of the earth, of the distribution of, the different races of the human family, and the various combinations which have arisen from their repeated intercourse, are subjects of the highest consequence, and to the clear understanding of which our maps and charts can only serve as the foundation stone. No doubt the commercial intercourse of mankind is facilitated and kept up by these maps and charts; but we should aim at a higher object in the study of geography, viz. the improvement of man's moral culture by a more extended knowledge of the productions of different climes, and by bringing before him, on a large tabular scale, the moral and physical conditions of his race.

With this view of the importance of the subject before us the following instructions have been prepared; but before attempting to point out the particular objects to which, in reference to geographical observations, the attention of travellers should be more immediately directed, it is, perhaps, advisable to mention a few general points which should be constantly borne in mind as the basis of all observations, inasmuch as without them all individual remarks, however carefully made at the moment, will ever be desultory in their character and unsatisfactory in their results.

Most prominent amongst these general points is the necessity of acquiring a habit of writing down in a note-book, either immediately or at the earliest opportunity, the observations made and the information obtained. Where numbers are concerned, the whole value of the information is lost, unless the greatest accuracy is observed; and amidst the hurry of business or professional duties the memory is not always to be trusted. This habit cannot be carried too far. A thousand circumstances occur daily to a traveller in distant regions, which from repeated observation may appear insignificant to himself, but which, when brought home in the pages of his note-book, may be of the greatest importance to others, either as affording new information to the scientific inquirer, or as corroborating the observations of others, or as affording the means of judging between the conflicting testimonies of former travellers.

It is also important, in order to secure accuracy, that the observations should be noted down on the spot. It is dangerous to trust much to the memory on such subjects; and if the observation be worth making, it is essential that it be correct. And here it may not be inappropriate to hold out a caution against too hasty generalization. A traveller is not justified in concluding that, because the portion of a district, or continent, or island which he has visited is wooded or rocky, or otherwise remarkable, the whole district may be set down as similarly formed. He must carefully confine himself to the description of what he has himself seen, or what he has learned on undoubted authority.

Again, to the geographer, the constant use of the compass is of the greatest consequence. No one attempting to give geographical information should ever be without this instrument. The bearings of distant points, the direction of the course of a river, however they may be guessed at by the eye, can never be accurately laid down without the compass; and these observations should be immediately transferred to the note-book. This and his compass should on all occasions be his constant and inseparable companions. In using the former, he should not forget that slight sketches of the country, and of the peculiar forms of hills, however hastily and roughly made, will often be of more assistance in recalling to his own mind, or in making intelligible to others, the features of the district he has visited, than long and elaborate descriptions. Let him then acquire the habit of never quitting his ship without his note-book and pencil, and his pocket-compass, and the traveller who acquires the habit of constantly using them with readiness will never have reason to regret the delay or the inconvenience which may have temporarily arisen in providing himself before starting with such useful companions.

Having made these few introductory remarks, equally applicable to most other branches of science, let us proceed to describe as briefly and succinctly as possible some of the principal features to which the attention and the inquiries of the young geographer should be chiefly directed. For this purpose the subject of the present memoir is divided into two heads, which, without straining the use of words, may be not inappropriately called Physical and Political Geography. By physical geography is meant everything relating to the form and configuration of the earth's surface as it issues from the hand of nature, or as it is modified by the combined effects of time and weather, and atmospheric influences. By political geography all those facts are implied which are the immediate consequences of the operations of man, exercised either on the raw materials of the earth, or on the means of his intercourse with his fellow creatures.*

I. PHYSICAL GEOGRAPHY.

The study of physical geography has of late years made considerable progress. In proportion as the more extensive and careful observations of geologists have led to a clearer conception of the principles and details of that science, the importance of more correct information respecting the physical features and outward forms of the component parts of the earth's surface has been recognised even in a geographical point of view. For without invading the province of geology, it is evident that many modifications of the surface of our planet are constantly, indeed almost daily, taking place, which may be distinctly traced to the peculiar conformation of some of its physical features. A lofty mountain or a projecting headland may be the indirect cause of a distant sandbank or a shoal. The effect produced by these features in modifying either a gust of wind or the set of a current is enough in the lapse of ages to cause such an accumulation of materials in particular spots as will occasion these phenomena. Thus it becomes important, with reference to the mere geographical outline of a country liable to such modifications, independently of pure geological causes, to ascertain and describe all those features by which such important changes may be effected.

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* An Italian writer of considerable eminence, Count Annibale Ranuzzi, in a little work published at Bologna, 1840, entitled 'Saggio di Geografia Pura,' divides geography into two branches, which he calls pure and statistical geography: the former professes to describe the results of physical forces, the latter the effects of moral force; the former is expressed by measurement, the latter by numbers.

But independently of these direct changes, the physical outlines and features of a country exercise a great influence in modifying its meteorological character, as well as the social, political, and commercial position of its inhabitants. In vain should we look for much commerce amongst a people whose country possessed no navigable rivers; in such a case the sea-coast alone, if easily accessible, might offer a few points where trade or barter could be carried on. A sea beset with coral reefs and rocky islets will offer to the observation of the naturalist a series of phenomena entirely different from those offered by one free from these obstacles to navigation. Again, the climate of a country will in many respects be regulated by its physical character. The nature of the soil and the form of country will mainly determine the amount and character of its vegetation. The retentive qualities of clay forming the basis of a low plain will support a rank and marshy vegetation very different from that which will prevail in a hilly or mountainous district: all these various qualities of vegetation will in their degrees exercise considerable influence on the climate, particularly when taken in conjunction with its greater or less proximity to the equator. The climate, again, cannot fail to influence the habits, social developement, and civilization of the inhabitants, as well as the Natural History of each particular country. Thus we trace a close connection between its physical configuration and those questions which have to be discussed in considering, in its most extended sense, the geographical features of different districts.

In order to bring together the various points to which the foregoing observations refer, they may be arranged under the following heads, which will be found to embrace most, if not all, of the important features of the subject, and respecting each of which it will be necessary to say a few words.

1. Form of country; whether consisting of hills, valleys, or plains.

2. Mountain ranges; their direction, height, slope, and spurs; their woods and forests.

3. Rivers; their sources, obstacles, size, and mouths; their beds and banks, affluents and confluents.

4. Springs; whether hot or cold or mineral; their localities, temperature, &c.

5. Lakes, marshes, lagoons; how surrounded, and when supplied with water.

6. Coast-line, sand dunes, harbours; nature of shore, whether sandy, rocky, or muddy.

7. Oceans; their depth and currents; islands, rocks, shoals, &c.

1. *Form of country; whether consisting of hills, valleys, or plains.*—The physical configuration of a country is the first object which engages the attention of a traveller on entering a new locality, and this may be described in general terms as flat, undulating, hilly, or mountainous; or the country may be divided into districts, to each of which one of the above terms of configuration may be applied. Each of these, however, is susceptible of great modification. A *flat* country may be a sandy desert, a rich alluvial plain, or a marshy, boggy tract; it may be well watered by rivers and streams, or arid and parched up; it may contain numerous lakes; it may be barren, or wooded, or cultivated as arable or grass land; each of these features may be of importance, or at least of interest: nor must the nature of its soil be omitted, whether sand, or marl, or clay, as the appearance of the country will often depend greatly on this circumstance. In some cases the plain may stand at a

higher level than the surrounding country. Such elevated plains are usually called uplands, or plateaux (*Hoch ebene*, in German). Other important characteristics of a plain are its form and extent, and the natural features by which it is bounded, whether by mountains, rivers, or seas; how many miles wide, and how many long; whether extending parallel with the coast, or running up between hills into the interior.

Many of these characteristics, it will be observed, belong equally to the other forms which constitute the character of the district. An *undulating* country may be barren, wooded, or cultivated; it may be arid, or watered by streams, &c. The undulations may be abrupt, or only gently swelling, and this may be in a great measure owing to the nature of the subsoil, whether it consists of gravel, or sand, or rock. A country of this description is easily described, but a *hilly* country, on the other hand, is more complicated. Not only is the term vague and uncertain, but other features have to be considered in reference to it. Neither hills nor mountains can exist without valleys, respecting which also there are many points of interest deserving notice, which will be farther alluded to hereafter. Then, again, the hills themselves may be of various forms and characters: Do they extend in long parallel chains or ranges, or are they detached and isolated? Do these ranges of hills radiate or converge? Do they rise abruptly or gradually from the low country? and how are they wooded? What do the rocks which constitute their nucleus and their flanks consist of? If possible, it is desirable to ascertain their height, which, in the absence of complicated instruments and barometers, may be obtained approximatively by marking the exact point at which pure fresh water boils. It is a well-known fact that water, when heated in an open vessel, boils at a *lower* temperature in proportion as we ascend to a *higher* elevation above the level of the sea. It is hardly necessary to observe that the same accuracy cannot be obtained as with the barometer, but much may be done with the help of well-graduated thermometers. The apparatus for this purpose is very simple, and not liable to the same derangements as the barometer. On a limited scale, and where the means of comparison are at hand, the aneroid barometer may be used for this purpose with great advantage. Another simple method of measuring the height of mountains within sight of the sea is by taking the angle of depression of the sea-horizon, from which the height of the station may be calculated by a very simple formula.

2. *Mountain ranges.*—The most important features in the configuration of a country are the mountain ranges by which it is traversed. The exact point of distinction between a hill and a mountain is difficult to describe; in some cases it will be purely comparative, in others it will depend on the general character of the country, and in some it will be arbitrary. But in all cases it will be desirable to endeavour to ascertain the height of the principal points, the direction of the main ranges or chains, and whether they are parallel or not. The ridges may be *serrated* (jagged like a saw), or smooth and even, and the summits themselves will be either pointed, or dome-shaped, or flat. Is the mountain insulated or not? and if so, is it conical and sloping on all sides to the surrounding plains, or does it consist of a detached ridge? Many of these points will be found to depend on the geological formation of the country, and, as we have already observed, this branch of our subject is very closely connected with geological science. Ascertain also how far the mountain tops are covered with perpetual snow, and how far down their sides snow lies during the whole or any considerable portion of the year, and how far glaciers, if they exist, can be traced down the valleys, as well as the extent of lateral or terminal *moraines.* Is there any marked difference in the slope on the one side or on the other? Does vegetation abound more on one side than on the other? *e.g.* in Asia Minor it has been observed that the mountain ranges which extend from east to west (and this is their principal direction) are covered on their northern flanks with

luxuriant vegetation and magnificent forests; while the southern flanks, exposed to the rays of an almost tropical sun, are void of vegetation, barren, and generally rocky. This superior vegetation on the northern flanks is probably owing to the less rapid melting of the snows or drying up of rain there than on the southern flanks; consequently, south of the equator, the phenomena would be reversed. It may also sometimes be owing to the fogs and vapours driven up by the sea breezes, condensed on coming in contact with a colder body, or attracted and retained by the hills themselves. But here, again, we enter on the province of the botanist; and yet the geographer should inquire how far vegetation extends up the mountain side, and what are the changes which it undergoes. How far is it influenced by the change of soil, or the abundance or absence of springs?* Nor is our information respecting a mountain chain complete, unless we know the length to which it extends, and the breadth of country which it covers.

Valleys are a necessary complement to mountain masses, and there are many peculiarities connected with them well deserving observation. Are the sides precipitous or sloping? are they wide or narrow? well watered or arid? wooded or barren? Do the rocky sides correspond with each other in their salient and re-entering angles? How far do they extend into the bosom of the mountains? and how are the subordinate valleys connected with the principal one? There is also another peculiarity of valleys not to be lost sight of. There are some which convey to the traveller the impression that he is passing through a mountainous or hilly country, so steep, rugged, and lofty are the hills by which he is surrounded. It is only on reaching their summit that he becomes aware that the country through which he has been passing is an extensive plain, or table-land, intersected by deep chasms and valleys, opened out by volcanic action, or cut through the soft soil by the constant efforts of the streams by which it is traversed; such valleys of excavation as these have been sometimes not unaptly called negative valleys.

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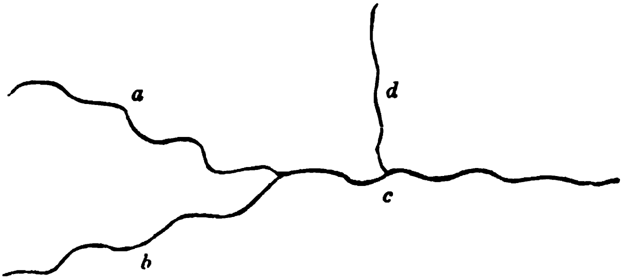
* The illustrious Humboldt, the most distinguished of living travellers, is a fine example of the importance of a knowledge of botany to the true geographer.

3. *Rivers.*—Scarcely less important than the study of mountains is that of the effect of rivers in modifying the geographical configuration of a country. From their sources in the mountain recesses to their final disemboguing in the ocean, their course, their currents, and their shores afford an endless variety of remarks and observations. The depth and colour of the water, the rate at which it flows, the cataracts it forms with the rocks over which its waters are precipitated, the eddies and currents by which its course is marked, are all deserving of notice, as are also the rocks and shoals which obstruct its uniform progress, either interfering with its navigation, or, by projecting beyond its ordinary banks, throwing back the rushing torrent on the opposite shores, as has been so graphically described by the Latin poet:—

Vidimus flavum Tiberim, retortis
Littore Etrusco violenter undis,
Ire dejectum monumenta regis,
Templaque Vestæ—

thus causing the gradual fall of the cliffs by undermining their precarious foundations. Nor in noting the size or extent of rivers should we neglect to state how far they are navigable, for what vessels, and by what means; whether the mouth is constantly free, or whether closed by a bar, and how much water there generally is over it, and how far up the tides usually extend. Some rivers, however, are not only closed by a bar, but, as in the case of Western Australia, are, during periods when the water is low, completely masked by the sand-hills or dunes which are blown up, forming a continuous bank with the hills which skirt the shores, and only when freshets of more than ordinary force come down are these sandy barriers overthrown, and the rivers enabled to find an uninterrupted outlet. In other cases the effect of beaches thrown up by the constant set of currents in one direction is not so absolutely insurmountable, the streams are only partially deflected from their proper course, and, instead of flowing into the sea in a continued line, are compelled to run for some distance parallel to the coast, until the accumulated backwater has acquired sufficient power to overcome the diminished resistance of the sea-beach: this, however, more properly belongs to the consideration of the coast-line.

But the description of a river will be imperfect, unless we also state the number and character of the streams which fall into it. And here we have to consider the angle at which the rivers join each other, whether the direction of the main stream is altered or not by the junction, the relative size of two confluent streams, and which of them may be said to preserve its former course with the smallest deviation. On the true description of these details must depend the question as to which of two confluent rivers should be considered as the main or parent stream. Rivers are said to be confluent when both branches are nearly equally deflected from their former direction, and the united streams may be said to be the resultant of two contrary forces. An affluent is a stream which falls into another, called the recipient, without changing the direction of the latter, and entirely losing its own.



a and *b* are confluent streams, *d* is an affluent falling into *c*, the recipient.

An affluent, too, will generally be found to be smaller than its recipient, and may often be more correctly called a rivulet or a torrent; and here it may be remarked that there is great advantage in attending to the true and proper use of these relative terms, rivers, torrents, rivulets, or brooks, the two latter being more or less synonymous, and a torrent being generally applied to a rapid mountain stream; all these, more or less, bring down from the hills detritus, which is deposited at the mouths of the streams, or wherever other natural causes retard the rapid flow of water. In these cases deltas are formed, which deserve examination, and are either fluviatile, lacustrine, or marine, according as the river empties itself into another river, a lake, or the sea.*

But there are other important characters which deserve attention in the description of a river; and chiefly the *name* s to be considered. Does it change during its course, and where and when? How far up from the mouth is the same name preserved? and is it the same on both banks? What is its origin, and by whom was it first given? Then we must inquire what islands are met with in its course? Where are they situated? Are they low? subject to inundation? marshy or rocky? or do they stand high above the level of the stream? Are they cultivated or not? What are their natural productions? By what animals are they inhabited? Again, is the river at all affected by rapids, or shoals, or cataracts? and what are the peculiar characteristics of these impediments to navigation? Does the tide flow in them, and how far up is it felt? Does the river abound with eddies or whirlpools, and how are they occasioned? Do they interfere with navigation or not? Are they accompanied by rocks or shoals? Again, we must ascertain what fords a river offers, and what depth of water is generally found over them: the nature of the bed of the river, particularly in the case of a ford, should also be carefully ascertained.

In addition to these remarks, many other important peculiarities will often occur to the careful observer. In some countries, particularly in secondary limestone districts, the rivers are remarkable for their subterranean courses.* Suddenly emerging in large volumes from the bases of lofty mountains, they flow across rich alluvial plains, and are then as suddenly lost in the cavities of another mountain, again to issue forth to the light of day in a distant region, after their subterranean courses. Nor should the traveller omit to notice, when crossing a river, the direction in which it flows as regards his own route, whether to the right or to the left. Instances are not wanting of distinguished travellers having been unable to connect their observations from not having sufficiently attended to this point.

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* See Col. J. J. Jackson's work, 'What to Observe.' London, 12mo., 1841.

4. *Springs.*—The phenomena connected with the outbursts of water from the surface of the earth are not only of the greatest interest, but a correct observation of them will be attended with much practical advantage. The traveller should state, approximatively at least, their size or volume, and the nature of the rock or soil out of which they rise; also whether they are pure or mineral, and what deposits are formed about the orifices through which they issue; how they are affected by different seasons; whether their flow of water is constant or intermittent, like the famous spring described by Pliny on the shores of the Lake of Como; whether they are of ordinary temperature or thermal; and if the latter, it is desirable to ascertain the degree of heat by means of a thermometer: the touch alone is a very vague and uncertain test. Let him endeavour also, when it can be done conveniently, to procure specimens, in closely sealed bottles, of the water of such springs as appear to possess mineral properties, or to contain salts in solution, for the purpose of analysis at home. Naval officers whose ships are at hand have in this respect great advantages over

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* Styria and the neighbourhood of Trieste. The loss of the river Mole in the chalk of the North Downs in Surrey is an instance of this phenomenon on a small scale within a distance of 25 miles from London.

those whose only mode of transport is on horseback or on camels.

5. *Lakes*.—These sheets of water, varying greatly in size, form very important features in the geographical description of a country, and the traveller should carefully remark their connexion with the other hydrographical characters of the district. Whether they constitute the sources of rivers, or are their ultimate recipients; whether they are or are not connected with the ocean or other great seas; their levels with regard to the ocean, particularly when at a lower level; what rivers, if any, flow into or out of them, and whether they contain fresh water or salt.

The following remarks from Colonel Jackson's work, already quoted, are very appropriate:—"With regard to lakes in general, the observations to be made upon them may be comprehended under the following heads:—

"Name; geographical and topographical situation; height above the level of the sea, and as compared to other neighbouring lakes; subterranean communication; form, length, breadth, circumference, surface, and depth; the nature of the bed and of the borders; the transparency, colour, temperature, and quality of the water; the affluent streams and springs; the outlets, the currents; the climate, soil, and vegetation of the basins; the height and nature of the surrounding hills when there are any; the prevailing winds; the mean ratio of evaporation compared with the quantity of water supplied, and any particular phenomena; the navigation and fisheries of the lake; formation and desiccation of lakes." This latter point, depending as it often does on the relative elevation or subsidence of the country, belongs also to the kindred science of geology.

Connected with the question of lakes are the scarcely less important features of lagoons and marshes, and smaller hollows or ponds; the extent of these should be ascertained, as well as whether they are connected with the sea or not, and what portions of them become dry and passable during the summer or at other periods of the year. Peat bogs, in many cases the remains of former lakes, may also be classed amongst these features, and their extent and depth and qualities should be ascertained.

6. *Line of coast, &c.*—This may be indeed said to be the peculiar province of the naval officer, and has been more fully treated of under the head of Hydrography; but as it forms one of the chief boundaries of those great geographical subdivisions, the details of which we have been here alluding to, we must not omit a brief allusion to some of its most important features. And particularly, with regard to the actual line of coast itself, the traveller should remark the various headlands jutting out into the sea, as well as the deep bays and recesses running up into the land, and affording refuge from the dangers occasioned by the neighbouring headlands; and he should also notice all gaps and breaks in the continuity of hills or cliffs or mountain ranges, the occurrence and nature of rivers and streams emptying themselves into the sea, the character and extent of their mouths, the nature of the detritus and alluvial matter brought down by them, and whether or not deltas are formed near their mouths. In another aspect he should inform us whether the coast is bold or flat, whether formed by cliffs or by sloping plains, and whether the rivers enter the sea by one or by numerous channels; and, if circumstances should enable him to do so, whether the coast is clear from danger, or whether sunken rocks and reefs render more than usual precaution necessary in approaching it; whether the sea deepens gradually or suddenly, and whether there are any extensive shoals or sand-banks near the shore; and whether these appear to belong to the same formation as the adjacent mountains, or to have been carried thither by tides or currents, &c.

It is also desirable to obtain the fullest information respecting the changes which take place from time to time either in the line of coast or in shoals and sand-banks. The latter, particularly when occurring near the mouths of large rivers, or of such as bring down much detritus from the interior, like the Mississippi or the Ganges, or even the Hermus in the Gulf of Smyrna, are very liable to shift, according to the prevailing winds and currents at different periods. The line of coast is also often subject to considerable changes in itself, in some places gradually extending out to sea, in others eating its way as gradually back inland; and it is remarkable that it is precisely the bold and lofty cliff which appears to offer such an insuperable barrier to the ocean waves, that crumbles away under their never-ceasing attacks, particularly when unprotected by a sloping talus of shingle; while the low, flat, marshy coast, offering no visible resistance to the advancing waves, and constantly covered by the muddy waters, is that which, owing to the deposits of mud and silt left by each succeeding tide, is gradually raised above its former level until it forms a real barrier to the waves, while it is slowly extended by the same process far beyond the spot which the sea formerly reached.

The nature of the shore also should be carefully ascertained, whether it consists generally of sand or mud, or rocks, either in the shape of reefs, or occurring as detached blocks; also whether the landing is easy or not on the beach, and whether this consists of sand or shingle. What bays or coves occur along the line of coast to serve as harbours of refuge? What is the nature of the anchorage? Are there any harbours along the coast? and how far have natural harbours been rendered more available and safe by the erection of breakwaters or piers?

7. *Oceans, their depths and currents; Islands, Rocks, Shoals, &c.* —With regard to the ocean itself, many of the objects of inquiry are the same as those which have been already mentioned with respect to lakes. Its depth and its colour, as well as other peculiarities, must be noted. The nature of the bottom should more especially be ascertained by soundings, whether consisting of mud or sand, or rock, or whatever other substances may be brought up from the bottom; when varied, the extent of each should be noticed. Not only is the important question of a good holding ground or anchorage connected with these facts, but the natural productions to be found in different seas depend chiefly on

the character of the bottoms, and the algæ and other marine plants which grow on them. The direction and strength of currents must also be observed, as well as their prevalence or usual duration, where liable to change. Prevailing winds should also be noticed. The great improvements introduced into Atlantic navigation, particularly amongst the Americans, since the publication of Lieutenant Maury's charts of the winds and currents of the North Atlantic, afford the best proof of the value of these observations. Tides also must not be forgotten: their amounts as well as their periods and durations are important. In some inland seas they appear to be rather influenced by meteorological than astronomical causes—to be dependent on the force of regular winds rather than on the attraction of the sun and moon. But other incidental peculiarities also require notice, such as storms and tempests, hurricanes and tornadoes, particularly when of frequent occurrence, or when recurring at regular intervals or at certain periods of the year. The permanent effects produced by them (if any) should also be registered, such as surfs, breakers, rollers, &c.

In the next place the maritime geographer should direct his attention to the islands, rocks, or shoals which occur in different seas; their extent and position should be carefully noted, as well as the depth of water round them; their harbours and facilities for landing; what supply of fresh water can be obtained; whether near the shore or not, or whether convenient for watering ships, &c.; what rivers or streams are met with, as well as their natural productions. Reefs and rocks, whether visible or sunken, and constantly below the surface of the water, as well as shoals, should be examined and described, and the depth of water over them carefully ascertained.

In concluding this first division of the subject, we must also mention a few points connected with the physical features of the country, which, being of an accidental rather than of a normal character, did not easily find a place in the more obvious subdivisions of the subject. The traveller should pay particular attention to those phenomena in the physical structure of the country which are sometimes called natural curiosities. Amongst the principal of these are grottoes, caves, and caverns: some of them are not only strikingly beautiful, but of great scientific interest. They are more usually met with in limestone districts than in any other; it is interesting to ascertain their size and extent, and the distance to which they have been traced. Are they traversed by subterranean streams; and if so, do these streams enter or escape by known channels or mouths, as is frequently the case in Istria and Carniola, and in the west of Ireland? Natural bridges present another instance of this kind of phenomena. How have they been formed, and what is the nature of the rock of which they consist? Are they stalactitic, or of a more compact nature? Mines are also to be noticed, although they come more directly under the head of geological observation. Volcanic phenomena and earthquakes are also deserving of notice. Springs of fresh water rising up in the sea are not of unusual occurrence; and any information respecting them is always desirable, such as the depth of water, and the effect of the fresh water on the surrounding ocean. Within the last few years several ancient sites on the coast of Greece have been satisfactorily identified by the discovery of these interesting springs. Any instances of that remarkable phenomenon observed in Cephalonia, where the sea-water constantly flows inland into a hollow in the rocks, should also be carefully described. In short, it may be safely asserted that there is no single fact connected with the physical structure of the earth, falling under the notice of an intelligent observer, which may not be of value or importance either to himself or others, if he will only give himself the trouble of carefully noting it down on the spot, with as much accuracy and detail as circumstances will permit. With this view we must again urge what was stated at the beginning, and would add, in the words of Mr. Darwin, "Trust nothing to the memory; for the memory becomes a fickle guardian when one interesting object is succeeded by another still more interesting."

II. POLITICAL GEOGRAPHY.

We now proceed to notice some of the principal features to which attention should be directed on the subject of political or statistical geography. In many respects this branch of our subject approaches very closely to that either of statistics or of ethnology, to the consideration of which distinct and separate articles will be devoted; we will here however endeavour to confine ourselves to the definition already given, and to avoid those questions of detail which are more peculiarly the province of the statist or of the ethnologist. Nor can it be expected that the casual visitor should devote to the examination of documents and books the time that is necessary to arrive at any important results in reference to these questions, or to make much progress in the investigation of a subject, however important, when the whole value of the information depends on the extent and minute accuracy of its details; but yet there are many matters connected with man's social state which the traveller may easily elucidate by availing himself of the opportunities thrown in his way, and carefully preserving the information he obtains.

This branch of our subject may properly be divided into the following heads:—

1. Population; different races of inhabitants.
2. Language; words and vocabularies.
3. Government; ceremonies and forms.
4. Buildings; towns, villages, houses.
5. Agriculture; implements of labour and peculiarities of soil.
6. Trade and Commerce. Roads and other means of communication.

1. *Population.*—One of the most interesting inquiries on visiting new countries relates to the habits and customs of the people by whom they are inhabited. But the oral in-

formation first obtained by a stranger is almost invariably incorrect, and particularly so in barbarous countries and amongst an ignorant population, where truth and accuracy are equally disregarded. Various sources must be referred to before we can venture in such cases to place confidence in our information. Another and more interesting question, as regards the population of a country, is the nature and character of the races by which it is inhabited; we wish to know whether they all belong to one of the great races of the human family, or to a mixture of several; how far the national character has been affected or modified by such mixture; whether such changes took place long ago, or are of recent occurrence. In many instances casual intercourse with the natives will lead to information on this subject; local traditions will be found to have been preserved, which, after making due allowance for exaggeration and prejudice, will often give a clue to the details required. It is also worth noticing, when the population consists of various races, whether one race or nation is more confined to a rural or a town life than the other; whether there exists any feeling of hostility or jealousy between them; whether any particular trades or occupations are more exclusively practised or followed by one race than the other; whether one race is kept down or oppressed by the other, or whether they enjoy a state of comparative equality.

When the population of a country has up to a certain period consisted of one race, and a mixture has subsequently taken place, this change may have been occasioned in three different ways. The new race may have come down with force and violence on the original inhabitants, and, having gained possession by right of conquest, may have constituted themselves the masters of the country; or, secondly, they may have been introduced as slaves in the first instance, captured in war or taken by stratagem by their more successful neighbours; or, thirdly, they may have come gradually, few at a time, with the free consent of the inhabitants, seeking to make their fortunes in a new country as settlers or as colonists. Any information on these points, where a mixture of races exists, will be interesting. Not only will the moral character of the united people be differently influenced, but even their political rights, their institutions, and form of government, will have been greatly modified according to the different modes by which the union of the two people was effected.

In many cases, too, the traveller may have opportunities of making useful observations respecting the general character and disposition of a people. Are they of a warlike or a peaceful disposition? Have they made any progress in the arts of civilization or of commerce? Do they possess any and what extent of literature? Are they remarkable for their honesty, or for contrary propensities? Are they open and frank towards strangers, or the reverse? Do they make any distinction in their dealings between natives and foreigners? How do they dress and live? What are their domestic habits and relations? Do they encourage or prohibit polygamy, and are women treated with respect and consideration? Without going profoundly into the study of these questions, the attentive observer cannot fail to pick up many interesting details and facts on these subjects, all of which may hereafter be of use to himself or to others.

2. *Language.*—The traveller will have many opportunities of collecting much interesting information respecting the languages of those countries which he visits, by taking notes of all the peculiarities he may observe respecting them, when he feels confidence in the accuracy of his information. These observations do not of course apply to the languages of Europe, and to those of the more civilized nations of the East, viz. the Arabic, the Persian, or Mahratta, &c., but are rather intended for the guidance of those who visit the islands of the Pacific, or the Indian Archipelago, Australia, Africa, and other lands, of which the languages are still almost or entirely unknown.

In this respect there will in all probability be great analogy with the previous subject. Where a nation has sprung up from the fusion of two races, it will generally, if not universally, be found that the language bears traces of the same admixture. The various elements of combination will have produced an analogous result in a language partaking of the essential characters of those of which it was composed. Any information, therefore, showing how far the grammatical construction of the resulting language or particular words are derived from one or the other of the parent tongues, will be important. Nor should these observations be confined to mere words, and their affinities in different languages. It is equally desirable to obtain information respecting the genius and character of languages; to remark how far the idioms of one correspond with those of another; and whether the resemblances observed between the languages of various nations can in any way be traced to any original connexion between the nations themselves, or to political or commercial relations existing between them at a former period.

But it is not alone with reference to the comparisons to be made between different languages that it is desirable to obtain correct information. Even when the traveller has no opportunity of comparing several languages, he may collect much valuable matter by attention to any one in particular. Above all things let him endeavour to make as complete a vocabulary as possible of all those words of which he can depend on obtaining the true and precise meaning. We would recommend for imitation the example of Lieut. F. E. Forbes, R. N., to whose exertions we are indebted for the discovery of traces of a *written* language amongst the negroes on the west coast of Africa.* Nor are words alone to be attended to: all peculiarities of diction, all idiomatical expressions and phrases ought to be remarked and carefully written down. With respect to the languages of many barbarous yet interesting tribes, it is only by the repeated observations of successive travellers, and by the comparison of such observations with those of others in different regions, that we can at least obtain any idea of their nature, their genius, and their origin. It may also be useful to ascertain how far foreign words have been introduced into the language, and to what extent they are used—whether confined to one or more classes of the population—whether they are more particularly used by the military, the commercial, or the manufacturing classes.

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* See Journal of the Royal Geographical Society, vol. xx. p. 89.

3. *Government.*—It is hardly to be expected that those for whom these remarks are principally intended will have the time or opportunity to make many inquiries, or to collect much correct information, on the details of government in its various branches, in the countries they may visit. Many of these details, even if they could be obtained, would be more appropriately noticed under the head of Statistics. There are, however, several points connected with this subject on which an intelligent traveller can hardly fail to make useful and interesting observations. Amongst these we may mention all kinds of forms, ceremonies, and processions, whether of a religious or civil nature; the observance of religious rites, where strangers are not superstitiously excluded; the ceremonies and processions which are generally a part of such rites, and which for the most part take place in the open air, afford many opportunities for remarks. It would be desirable to know how far the mass of the people participate or are interested in these proceedings, also what effect is produced by them on the morals and habits of the people. Royal pageants and processions, military manœuvres and encampments, the dress and bearing of the troops, are all worthy of notice. Many municipal institutions necessarily come under the observation of travellers, as matters of police and surveillance, passports and other documents required by the authorities, as well as any other regulations necessary, or supposed to be so, for the maintenance of peace and order. What are the principal taxes, how are they levied, and on what articles are they imposed? What is the principle of taxation—direct or indirect?

Public institutions, also, in those countries where the state of society warrants their existence, and can secure their continuance, whether maintained by the liberality of the state, or supported by the zeal and resources of individuals, may well deserve a passing notice, even if more detailed information is not accessible. These, too, may be of very different characters, and may have various objects in view: they may be intended for the promotion of literature amongst the old, or of education amongst the young; they may tend to the furtherance of trade and commerce, or they may look only to affording amusement and relaxation. Something at least on all these subjects will not escape the eye or ear of the most casual observer.

4. *Buildings.*—In considering the buildings of a people, they present themselves to our notice under several points of view. We may, in the first place, consider them as public or private. Amongst the former we shall find such as belong to the nation generally, either as the residence of the sovereign, or as belonging to the different departments of the executive government, or to the legislature, or as devoted to the alleviation of suffering or to the maintenance of health, as poorhouses, hospitals, and infirmaries of various kinds. They may be devoted to the service of God, or to the deities worshipped by uncivilized nations, as churches, temples, mosques, and other similar edifices; or they may be intended for the advancement of literature and science, such as colleges and university buildings, museums, picture galleries, &c.; or erected for the amusement and recreation of the people, or for the furtherance of public business, as market-places, town-halls, theatres. &c. With regard to private residences, the different purposes are not so numerous; but even here we may distinguish the habitations of the rich and of the poor, and those intended for town or country residences; the different styles of villages in the country, and the character of streets and houses in the towns; villas, farm-houses, &c.; and, in some cases, the different dwellings of different tribes. This, in the case of those nomadic people who

still dwell in tents, or of savages who live in huts, is not only very varied, but will afford much interesting information respecting their social habits and mode of life.

Again, we may consider the buildings of a people either with regard to the degree of civilization of which they may be considered as the evidence, or in reference to the progress in art and architecture which they may be held to indicate. For this purpose, not only is it desirable to point out the style in which they are erected, but also the materials which have been used, and the mechanical contrivances by which they have been assisted. In this case slight sketches will often convey a clearer idea of the object than long and minute description. Nor should we neglect altogether another class of buildings, partly private and partly public in their nature, which often convey much information with respect to the character and progress of a people: I mean their tombs and other sepulchral monuments erected to the memory of the dead, or for the purpose of preserving their bodies. It may be observed that few things indicate more directly the progress of a people through different stages and degrees of civilization than the successive changes which have taken place in the style and character of their buildings, and of the arts by which these have been embellished, from the first rude attempts of Druidical and Cyclopean structure to the more elaborate and symmetrical proportions of what may be called the Palladian style.

5. *Agriculture.* — The geographer will have numerous opportunities, in his examination of a new country, of obtaining much valuable information on this subject and its collateral branches, by a little attentive observation and a few concise inquiries. Amongst the chief points to which his attention should be directed, we may mention the use of tools and agricultural implements, for the purpose either of cultivating the soil or of transporting its produce from one locality to another, the mode of ploughing and preparing the land for different crops, the manner of raising the crops themselves, of sowing, planting, and

transplanting, of reaping and gathering in, of threshing, and other similar occupations, the rotation of crops, and whether, and under what circumstances, more than one crop is raised in the year.

Other inquiries may be usefully directed towards the animals used for agricultural purposes or domestic economy, in the field or in the farmyard; whether they are indigenous, or brought from distant or neighbouring countries; to what uses they are applied, whether for draught, for food, or for clothing. How are they fed? Are they of a hardy or delicate constitution? Have any changes taken place of late years in the state of agriculture and tillage? Is it in a state of progress or decay? What is the feeling of the inhabitants towards it? Is it practised by the majority or only by a small portion of the population? What buildings form a part of agricultural capital? All these depend on the social state of the inhabitants. Is the pursuit of agriculture esteemed or despised? What are the usual prices of provisions — animal and vegetable? To which do the inhabitants give a preference? What is the principal produce of the country — vegetables, fruits, *cerealia*, butcher's-meat, or poultry? What is the tenure of land? Does it belong to the State or to individuals? Is it the common property of a tribe, or does each inhabitant claim a portion of it as his own? Is it distributed in large estates, or subdivided into small properties? Is it chiefly in fee, or held on long or short leases from year to year? Are rents paid in kind or in money or other substitutes, as the representative of given values? What is its chief feature—arable, meadow, grass, or woodland? What are the respective quantities of each? What is the nature of the soil, and what distinctions are there in it? Is one kind more adapted for one species of cultivation than another, and whence is this difference derived, and by what natural or artificial causes has it been occasioned or modified?

6. *Trade and Commerce.*—Our information respecting a country cannot be complete without some knowledge of its

trade and commerce, and the manner and the means by which they are carried on. In this respect, also, without stopping to inquire very minutely into the statistical details of the resources and means of a country, the traveller can add much to our information by the mere record of the facts which come under his own observation. The following are some of the principal points to which his attention may be directed: What is the nature of the trades chiefly exercised by the different classes of the population, and by different tribes, where such exist? Are they principally employed in working up the raw materials produced in their own country, or those imported from other quarters? Are they workers in metal, and whence are the metals obtained? Are they workers in leather and similar materials? Or do they spin and weave, and what are the materials worked up in their looms—whether wool, cotton, flax, or silk—and which of them, if any, are raised in their own country, and from what other districts do they draw their supplies when requisite? Is their commerce chiefly domestic, foreign, or transit, and by whom is it carried on? What are the principal articles of import and export? Where do they come from, and whither are they sent? What is the medium of exchange? What progress have they made beyond the mere principle of barter? Is money used as a medium of exchange, or are other substitutes employed, as cowries, salt, beads, cloth, or metals? What coins are known? Of what materials do they consist? Have the inhabitants any knowledge of bullion, paper, or bills of exchange? Have they any system of credit or bill-discounting? How is commerce conducted? What are the means of communication—water or land? If the former, what is the nature of their ships and vessels? Are they employed at sea, or on rivers or canals? What is the character of their sailors? If land communication is chiefly used, what is the nature of the roads and other tracks? Are they available for carts and waggons, or only for beasts of burden? What beasts are used—horses, mules, asses, bullocks, or camels? Which are most useful? How are the roads kept up? Are they in good or bad condition?

Are the bridges well built and kept in repair? What is the ordinary rate of travelling, and the expense of carrying goods? What are the weights and measures used in the country? Are they the same in trade or commerce as in private life? Many of these questions are easily answered, and all will be found useful for one purpose or another.

Having thus gone through the different heads above alluded to, there still remains a subject which calls for a few remarks. Our information respecting distant lands and their inhabitants cannot be said to be complete without some knowledge of their past history and of the remains of antiquities still left to attest their former condition; and we therefore propose briefly to point out to the traveller a few of the objects to which his attention may be advantageously directed on this question of comparative geography. Let him carefully examine the sites and remains of ancient buildings. Where the remains appear to indicate the site of a ruined city, let him carefully trace the line of the ancient walls, ascertain the position of the gates, describe or sketch their style of architecture, and state the materials of which they have been built. If the fallen fragments indicate the site of a temple or any analogous building, let the traveller endeavour to obtain precise measurements of its different component parts, the length and diameter of the columns, the details of architraves, capitals, and cornices, and of whatever other features may attract his attention. Above all things, let him diligently search for inscriptions, and then carefully copy *all* that he may find, endeavouring as much as possible to preserve the arrangement of lines, and the precise form of the characters in which they are written.

But other evidences of ancient art or history remain to be noticed—coins, and manuscripts, and works of art. With respect to the former, the traveller cannot be too industrious in collecting all that his means allow him to procure of those which come in his way—taking care, of course, in those countries where such practices obtain, that he is not imposed upon by forgeries. Manuscripts are of more rare occurrence, but even these may safely be collected when possible, and there is here less danger of deception than in the case of coins. With regard to works of art it is more difficult to lay down any precise rule, on account of their greater variety, as well as a certain degree of vagueness attaching to the term, and also on account of their bulk and cost. Two classes, however, may be mentioned which particularly deserve attention—statues and gems. Of the former of these the ordinary traveller will generally be enabled to make drawings, their size in most cases preventing their removal. Gems, on the other hand, whether cameos or intaglios, are amongst the most valuable and portable works of art which a traveller can collect. But here also let him beware of imposition; it is frequently and notoriously practised.

In concluding these observations, we must remark that they can only be looked upon as hints or suggestions of the sort of objects to which the geographer's attention should be directed. We are aware that many other features on the earth's surface might have been specially alluded to; but we trust that what has been here mentioned will suffice to point out the nature and multiplicity of the facts which it is important to notice. Geography, in the most extended sense of the word, embraces a multitude of subjects, and comes in contact with almost all the other branches of science which are noticed in this Manual. Hence the task of the scientific geographer becomes one of great responsibility. Astronomy, geology, botany, mineralogy, hydrography, ethnology, and statistics, besides other sciences, are all subservient to his duties. Whilst, on the other hand, without accurate geography, the sisterhood of science is incomplete. But we must not pursue this subject any further. Suffice it to repeat, and to assure the young geographer, that whoever brings back from distant lands accurate and well-digested facts on those and similar points to which we have directed his attention, will thereby be enabled to contribute his quota to the progress of universal science.

ARTICLE VIII.

THIRD DIVISION, SECTION 2.

STATISTICS.

BY THE LATE G. R. PORTER, ESQ.

[*Revised by* W. NEWMARCH, Esq., *Secretary of the Statistical Society*.]

Population.—THE *population of any place or country* must be considered as the groundwork of all statistical inquiry concerning it. We cannot form a correct judgment concerning any community until we shall have become acquainted with the number of human beings of which it is composed, nor until we shall have ascertained many points that indicate their condition, not only as they exist at the time of inquiry, but comparatively also with former periods.

The actual numbers of any population can never be so satisfactorily ascertained as by the interference of the government, and the first inquiries upon the subject should be for official enumerations. Where such do not exist, it may still be possible to procure data for satisfactory computations from governmental departments, and especially those connected with the taxation of the country; but it must be evident that, to render such data available, the circumstances under which they have been collected must, as far as possible, be ascertained and recorded. Where no official accounts can be made available, recourse should be had to private channels, giving the preference to such statements (if such exist) as may have been published in the country, and have thereby been subjected to criticism and correction on the part of those best qualified to form a judgment on the subject. Local registers are sometimes to be met with, where the central government has not interfered. Such were carefully kept in many parishes in England before any government census was undertaken. From such registers, by comparing births with deaths through a series of years, the population of a country may be estimated with some approach to accuracy. The rate of mortality is a fact of so much importance towards any useful knowledge of a country, that it is naturally among the subjects of inquiry that should earliest command attention. If registers of burials, which record the ages at which the deaths occur, can be obtained, they would elucidate many points of great interest as to the condition of the people and the effect of the climate, and would besides afford means, in connexion with the number of births and marriages, for more nearly approximating towards an accurate estimate of the population. Where a census has been taken, a distinction will doubtless have been made between the sexes; and, if the ages also have been recorded, the tables will themselves afford means for testing their general accuracy, as it may be assumed that the proportion of adult males—twenty years of age and upwards—is *about* one-fourth of the whole population. Where no census has been taken, it may be possible to ascertain the number of *fighting men*, that is, of males between given ages. Should all other sources of information be wanting, it will then be necessary to have recourse to oral information, in estimating the correctness of which the observer must avail himself of such aids as present themselves. The question whether a community is increasing, stationary, or diminishing, may be judged from the amount of buildings in progress, or of houses untenanted or in a state of decay. If any account is taken, for purposes of taxation or otherwise, of the number of inhabited houses, and especially if these should be divided into different scales, a little personal observation as to the average number of inhabitants to be found in each will furnish valuable information concerning the population; but to do this the inquirer must inform himself concerning the domestic habits of various classes of the people; the necessity for which caution will be made apparent by the fact, that, while in all England the average number of inhabitants to each house is under 5½, the average number in the metropolitan county exceeds 7½; while the number to each house in Dublin is 12¾, which is double the average number in all Ireland, where the house accommodation is generally of the most wretched description.

Employments of the People.—Having ascertained, as well as circumstances allow, the numbers of the people, it becomes of importance to know how they are employed. It cannot be expected that any one who is without the authority of the government for the purpose can succeed in ascertaining with minuteness the numbers occupied in each of the various branches of employment, but opportunity may probably be found for ascertaining those numbers in certain great leading divisions, following in this respect the more usual course of inquiry in this country, and distinguishing individuals as employed, first, in agriculture; secondly, in trade and manufactures; and thirdly, in all other pursuits. By knowing the proportionate number of any people who are employed in raising food for themselves and the remainder of the community, we possess a very important element towards estimating the social condition of the people. The truth of this remark is made apparent by the fact shown at the census of 1841, that, while in Great Britain 251 persons raised the food consumed by themselves and 749 other persons, or while 1000 persons engaged in agricultural labour supplied the wants of 3984 persons, including their own; in Ireland, in the same year, the labour of 662 persons was required to supply food for themselves and 338 others, so that 1000 persons supplied food for only 1511 persons, themselves included. The deductions to be drawn from the like facts in other countries are liable to modification, and particularly if it shall appear that families, or any portion of them, which draw their chief support from agriculture, employ any portion of their time in domestic manufactures. Previously to the inventions of Arkwright and Hargreaves, the spinning-wheel was in general operation in cottages throughout a great part of England; and the time is yet more recent at which the shuttle might be heard in those cottages during the long evenings of winter, and at times when out-of-door labour was prevented by bad weather. Handloom weaving, except as the substantive occupation of the family, may now be said to have ceased in this country, and the spinning-wheel has long been wholly superseded; but this is far from being the case in many, or perhaps in most, other countries, where the females of a family are at times employed in spinning and weaving, at least for the supply of their own household, if they do not provide a further quantity of fabrics for sale to others.

Where manufactures are carried on in factories or large establishments, it will not be very difficult to obtain a tolerably accurate estimate of the number of such establishments, and of the hands employed in them. In some countries the government requires that a patent or licence shall be taken out yearly by the proprietors of manufactories, and by this means a correct account of their number might be obtained. In the same way the number of dealers may sometimes be ascertained, and probably classified as being wholesale or retail traders, as well as distinguished according to the branches of business pursued by them.

It is desirable to know the usual and average size of *farms or holdings of land*, and the system under which they are cultivated, whether by the proprietor of the soil or by tenants; and, if by the latter, then upon what terms, whether by payment of an annual rent, and at what rate usually for a given measure; or, by a division of the gross produce, and then in what proportion the landlord participates for the mere use of the land and farm-buildings, or whether he furnishes the stock or any proportion of it. Inquiry should be made as to the existence of what is understood by "tenant-right;" whether by law or by custom the farmer is entitled to compensation for such improvements as he may have made in the condition of the land. The number and kinds of live animals that are bred and kept upon farms should, if possible, be ascertained, as well as the number of labourers usually employed upon a given extent of land; the rate of wages which they receive; whether those wages are lessened by reason of their being boarded by the farmer, or whether they live and board themselves in separate cottages; and also whether there is employment on the farms for women or children, with the rates of wages paid to them; and further, if the labourers have any other advantages in aid of wages.

Result of Labour.—If it be important to know how the people of any country are employed, it cannot be less so to ascertain the result of their labour. It is especially desirable to know the proportionate quantity of each kind of food raised upon farms of a given size, or upon any known measure of land of the average degree of fertility; the quality of such of the cereal grains as may be raised will best be ascertained by learning the weight of a given quantity by measurement. While making inquiries concerning the supply of food of home growth, it must be essential to ascertain whether, in seasons of average productiveness, that supply is equal to or greater than the ordinary consumption of the country. Should it fall short of the requirements of the people, inquiries should be made concerning the quantity deficient, and the sources whence the same is ordinarily made good. On the other hand, should the home produce exceed the consumption, the amount of that excess, and the usual channels employed for disposing of it, should be ascertained.

Similar inquiries should likewise be made concerning the *mineral productions* of the country. It will not be enough to know only the number of persons employed in mining operations, since the value of such labour varies exceedingly in different countries. It was stated at the meeting of the British Association in 1844, that, according to the official reports of the French government, each workman employed in the coal-mines of France raised no more on the average than 116 tons in the year, while the average quantity raised by each English miner in that time was 253 tons. Nor is this discrepancy confined to coal-mining. The quantity of iron made in Great Britain is four times that made in France, while the number of persons employed for the purpose is actually greater in France than in England: the numbers actually so employed in 1841 were, in France, 47,830, who made 377,142 tons of pig-iron; and in England, 42,418, who produced 1,500,000 tons of that metal—so that the labour of each man in France produced barely 8 tons, while in Great Britain it sufficed to produce more than 35 tons.

The like inquiries should be made with reference to every branch of occupation, as occasion offers or may be found. Upon this subject it is essential to know the *number of hours in the day during which, at various seasons of the year, workmen are ordinarily employed*, whether the routine of their occupations is disturbed by the intervention of holidays, and to what extent such interruptions are carried in different branches of industry. Also, whether any and what restrictions are placed by law or custom against the employment of women or children in any branch of trade or manufacture. Naturally connected with these inquiries is the share which the workpeople obtain of the value of the objects upon which their industry is employed. To ascertain this it is not only necessary to learn the usual rates of daily, or weekly, or yearly wages paid, but also the amount which a family of average industry, consisting of a man, his wife, and say four children, are ordinarily able to earn in the course of the year, including such perquisites as custom provides in aid of the ordinary wages, the nature as well as the value of which it must be interesting to know. It hardly needs to be said that a distinction must be drawn between the earnings of the skilled and those who are unskilled, those whose qualifications are the result of a previous expenditure of time and money, that is, of education, and those who bring little more than their bodily strength to the performance of their task. Neither does it need to be pointed out, that, however numerically important are the classes usually understood by the term workmen, their condition does not comprise the whole of what it is desirable to know in forming an estimate of a community; the circumstances of the better educated portion of the people, including those who by their studies and acquired skill influence so greatly the general well-being, and upon whom mainly depend the progress of civilization, are to the full as necessary to be known. It will probably not be difficult to learn, as respects these, the fees paid to professional men, such as physicians and advocates, the salaries of schoolmasters and mistresses, as well as the salaries and other emoluments of men employed in the higher and in the more subordinate offices of the government.

Coupled with these particulars, we should endeavour to ascertain the *necessary expenditure of families* in the various walks of life. This is a more difficult task, and it requires much knowledge of the various conditions of the community to estimate the correctness of such statements as may be gathered, especially as regards the expenditure of the poorer classes. It is a curious fact, that in almost every case where details of this nature were offered to the Commissioners of Poor-Law Inquiry in England, the expenditure as stated was found upon examination to exceed in no small degree the income of the family, although the parties affirmed that they did not run into debt. It must greatly help towards forming a correct estimate if the retail prices are ascertained of different qualities of the various articles used and consumed in families holding different ranks in the scale of society. The incomes of a very important class of public functionaries, the clergy, it may be more difficult to ascertain, especially in lands which have made a comparatively small progress in civilization, and where it is understood the priest often avails himself of the superstitious terrors of the ill-informed people to advance his own personal interest. In other countries, comparatively free from this evil, it is, however, not easy to ascertain the average rate of incomes of the clergy, which may be derived partly from one source and partly from another—sometimes from the State, by a direct payment; sometimes from land, the profit of which will vary from year to year; sometimes from fees given for the performance of certain religious offices, such as marriage, baptism, and burial; and sometimes also from voluntary payments, or offerings, in acknowledgment for the instruction and consolation imparted. Nor will the cases be rare in which several of these sources are combined, in order to make up the income. It will be more easy to learn the number of the clergy, and to ascertain the manner of their appointment, whether by election on the part of the people, or by nomination on the part of the government or of individuals; and an estimate may be made of their general incomes by observing the class of the community among whom they usually live upon a footing of equality.

Education.—There is no subject which will so well enable us to judge concerning the progress and probable future condition of any people as the state and degree of instruction which is provided for the youthful among them. The inquirer will therefore endeavour to learn, not only the number of educational establishments and of students attending them, but also the nature and quality of the instruction imparted; the proportion of schools connected in any way with the State, and of those established and supported by private means. It will not be difficult to judge from observation, and also through conversation with the inhabitants, how far the means provided have been effectual in former times in rendering the people intelligent, and in forming their characters. The cost of instruction should also be learned, and whether in any and what degree that cost is borne by the government; also whether any and what degree of proficiency in the usual branches of knowledge is requisite to enable any person to take upon himself any official duties, or to authorise him to assume certain responsibilities in society, where the fortunes, the happiness, and it may be the lives of others, will be intrusted to his charge.

State of Crime.—Closely connected with this subject is the state of crime in every country. The number of prisons, the amount of accommodation which they afford, and the number of inmates usually to be found within them, should, if possible, be obtained, as well as some acquaintance with the system of punishments pursued, and the treatment of prisoners. The number of executions that have taken place within a given number of years, and the nature of the crimes for which that extreme punishment has been inflicted, should be ascertained. If any more general record of offenders can be had, it would be well to inquire the prices of food during the particular years to which those records relate, in order to judge correctly concerning the moral character of the people under one of its most important aspects—its tendency towards criminal courses. To know the nature generally of the offences committed will give us an insight into many subjects of interest, provided the people have made any considerable advances in civilization; but if the country should be very backward in this respect, many crimes will go "unwhipt of justice." If the criminal records of England existed for any period further back than half a century, we should probably search them in vain in order to learn the number of pickpockets; not that the offence of picking pockets was unknown, but that when the offender was detected the mob took his punishment into their own hands, and, by pumping upon him, or dragging him through a horsepond, or by some other more convenient summary proceeding, satisfied their views of justice, and let the culprit go. It is very desirable to know among what classes of people offenders are chiefly found—whether among labourers in agriculture, or handicraftsmen, or others; and also whether educated persons add in any, and in what degree, to the list of culprits. It is highly important to draw a distinction between male and female offenders, since their proportionate numbers will throw light upon the general character of the community in some of its features. In the early part of the present century there were 40 females to each 100 males committed for trial in England and Wales; but during the 10 years from 1838 to 1847 inclusive, the average proportion has not been quite equal to 24 in each 100, indicating a change in condition, manners, and morals, favourable to the present day. It is equally desirable to know the proportionate numbers of juvenile offenders, classing under that head all under 15 years of age, or such other period of life as, under the influence of climate or any other cause, may determine the date at which the youths of the country generally assume an independent position and provide for their own support. It will be well to distinguish the sexes of these young offenders.

By making inquiries of intelligent residents it may be learned whether, with the progress of time, criminality has increased or diminished in the country. The criminal records, if such exist, will by no means furnish data upon which reliance can be placed for judging upon this point, since it often, or, it might be said, most frequently happens, that with advancing civilization the police regulations of a country are more strict; besides which, increasing population, and increasing wealth, may lead to a greater number of offenders, without really adding to the criminality of the community, since the nature and quality of the crimes committed may have become less serious. The number registered in the calendars will be increased if two cases of petty larceny shall have taken the place of one murder, and yet no one would thence affirm that crime has increased in the country.

Provision for the Distressed.—The *provision made for the indigent* generally, and especially for the sick and the aged among them, will naturally call for inquiry. The number and extent of establishments answering to our union-houses, alms-houses, hospitals, dispensaries, and lunatic asylums, should be sought for, with every particular that can be gathered concerning the manner in which they have been established and are supported, and the number succoured should be ascertained. It would be a service rendered to an important branch of science if the numbers, in proportion to population, were to be ascertained of lunatics, of blind persons, and of the deaf and dumb.

Public Roads.—The *length and condition of the public roads* should be inquired into, as well as the system under which their repair is provided for, whether by the State, or by tolls collected from passengers, or by the money or labour contributed by residents in the districts through which the roads are carried. The modes of travelling, as well as the nature and number of public carriages; and whether, as in some countries, they are the property of the government, or, as in England, the result of private enterprise, should also be ascertained, as they easily may be. The means for internal navigation, whether by rivers or by artificial canals, it may not be difficult to learn; recording the direction and the length of each, and the size of vessels in which the traffic can be conveyed. In the case of canals, it will be interesting to know the date of their construction, and, if possible, their cost, as well as the nature and amount of goods conveyed upon them (and upon the rivers also), the rate of toll, and the degree in which their construction has answered, both for the advantage of the community and the profit of the owners. The interest which attaches to railroads, in most places where they have been introduced, has been such as to cause every publicity to be given to their statistical conditions, and printed accounts may be easily procured, in which every question is discussed which it may be necessary to ask concerning them, and these should be secured.

Home Manufactures.—The *manufacturing industry* of a country will naturally claim attention, and the inquirer will, in the probable absence of all precise information concerning its extent, endeavour to supply its place by means of such circumstantial information as he can bring to bear upon the subject. With respect to such branches of manufacture as depend for their raw material upon foreign supply, it will not be very difficult to arrive at a tolerably close approximation to the truth in regard to the quantity of such material used. Such cases are comparatively few, however; and, with regard to those branches of industry which derive their material partly or wholly from the native soil, the person who visits any country must usually content himself with such statements as he can draw from trustworthy persons, preferring those accounts, if any such there be, which, having been published to the world, have stood the test of local criticism. The cotton and silk manufactures of England are examples of the first-mentioned of these conditions, while our linen and woollen manufactures sufficiently explain the other class. To ascertain merely the quantity of raw material used would go but a little way towards determining the value of any manufacture to a country. This will be plainly seen if we call to mind the familiar instance of the chain-cable and the watch-spring, both of which are products of the same material; while the latter, by reason of the amount of labour bestowed upon it, is many thousand fold more valuable, weight for weight, than the former. The cotton manufacture is open to the like difficulty, although in a minor degree; even the yarn, which is the result of a preliminary process, sells, according to its degree of fineness, from a few pence to as many shillings per pound. The inquirer will, therefore, feel it necessary to ascertain the increased value that is ordinarily imparted by processes of manufacture to the materials used, and whether any and what changes are going forward in this respect. The information here suggested may partly be gathered by comparing the prices of given weights and measures of the materials with those of finished goods of average quality; but it must be evident that little more can be done in this branch than to apply to men of intelligence and respectability for such information and opinions as they may be able to impart. It needs hardly be pointed out as desirable to know in what degree the general population shares in the use or consumption of home-manufactured articles—whether any part of them falls to the lot of the working classes, or whether they are wholly engrossed by the high-born and wealthy. It is desirable to know whether any, and what, branches of manufacture are carried on by foreigners to the exclusion of native workmen: also, if women and children find employment in manufactures; and further, if the degree of comfort in which the various classes of the manufacturing population live is greater or otherwise than the comfort enjoyed by those who follow other occupations. It is of importance to learn whether any manufactories are maintained or assisted by the government, and in what form that assistance is given; whether by direct money-payment or by the grant of privileges or monopolies; and in case any such system is followed, then whether in the branches thus favoured there is found a greater amount of success than ordinarily attends the employment of capital and skill in the country. The seats of the several manufactures should be indicated; and where any mechanical power is employed, the nature of the same should be explained; and also the degree of proficiency attained in the production of machinery when it is made in the country, and, if it is brought from abroad, then the places whence such machinery is derived.

Foreign Commerce.—The *foreign commerce* of a country is matter of especial interest to every country, and more particularly to England, so much of whose prosperity depends upon its commercial relations. Among the earliest inquiries to be made on this head will be the amount and description of the shipping under the national flag, and whether the same be increasing or otherwise; whether any, and what privileges are accorded to the native marine. Then, what other flags frequent the ports, distinguishing those which participate most largely in the trade, and whether they mostly or entirely trade with their own ports, or engage in the carrying trade from foreign countries.

Imports and Exports.—The *description and quantities of goods imported and exported* may usually be learned without much difficulty from intelligent merchants, or, what is better, from the accounts of custom-houses. Distinction should, as far as possible, be drawn between goods imported for use and those brought in transit, dividing them, in both cases, into raw materials and finished articles, and classifying them according to their nature, distinguishing food, clothing, metals, &c. The like statements should be obtained and distinctions made in regard to exports. It is desirable to know whether goods are imported directly from the various countries of their production, or indirectly from third markets, and in this latter case the reasons should be sought why the apparently less desirable course is followed. The rate of customs-duties can always be procured, and in most cases in a printed form. This will serve to show whether any differential or preferential duties are levied, to the hurt or advantage of particular countries. In regard to duties upon exports, their amount and nature should be sought equally with those charged upon imports and consumption.

Home Trade.—The *home trade of countries*, unless they be of such extent as to include different climates, and consequently to yield different products, is usually comprised in transmitting imported articles from the ports to towns in the interior and to country districts, or in transferring articles of home growth from the country districts to the different towns and ports. Besides this there will be, in manufacturing countries, the transmission of goods from the seats of manufacture to the towns and villages, for the supply of their inhabitants and of the neighbouring districts. A traffic of this kind it must be at all times difficult to register, and the most that can be done by a stranger or visitor is to learn the general nature and course of the trade, and to collect opinions as to its amount and condition at various periods of time. If any internal duties, answering to our excise-duties, are charged upon home productions brought into consumption, their nature and amount should be ascertained.

Currency and Banking.—The subject of *currency and banking* is of very high importance, and every information concerning it that can possibly be had should be carefully obtained. The nature and value of coins in use, their weights and denominations, should be noted, and whether means are used to prevent their exportation by laws passed for that purpose, or by the coins being made to contain any considerable portion of baser metal. If any auxiliaries to the use of coin should be established, such as bank or government notes, or transfers in books of public account, as practised in some trading cities in Europe (Hamburg, for instance), the nature of such should be described. Until a recent period the chief, if not the only method used for making payments in France, was by the transmission of silver coin; and it often happened that public carriages, passing between two places in opposite directions, conveyed at the same time tons weight of five-franc pieces. This inconvenient and expensive practice has of late years been in some degree remedied by the more general establishment of banks of issue, whose notes are transmitted by post, as well as by the extended use of bills of exchange.

Weights and Measures.—The *weights and measures* in use should be stated, with the proportions which they bear to those in this country, or to other well-known standards; and, connected with this subject, it is well to know what articles of general use are sold by weight and what by measure, and whether different weights or measures, or different usages in regard to them, are adopted in different parts of the same country, as was at one time the case in different parts of England.

Joint-Stock Companies.—If any *joint-stock associations* are in operation for trading purposes, their nature and the extent of their capital; the peculiar privileges, if any, that they enjoy; and the effect they are judged to have upon the general interests of the community, should be carefully gathered. There may be other associations not strictly trading, and yet closely allied to trading interests, which should equally be the objects of inquiry, such as docks, insurance-offices, and the like.

Public Revenue.—The *public revenue and expenditure* of countries, when published at all, are put forth by the government; and all statements of this kind should be made objects of inquiry, with a view to obtaining the same. If the government should not think fit to publish information of this kind, it will seldom be of any use to seek for it in any other quarter.

It is often possible to collect or to obtain access to lists or records of the *prices of commodities* for a series of years, and opportunities of that nature should not be neglected, taking care at the same time to obtain such information relating to local weights and measures as may fairly explain any references to quantity.

Municipal Regulations in the chief or principal towns, and the amount, nature, and incidence of local taxes levied by municipal authorities for purposes of police, water-supply, sewers, lighting, removal of nuisances, are important topics of inquiry. And in the same manner information should be sought upon the vital object of sanitary regulations, and the effects which have been found to be produced by any large employment of such regulations.

The extent of *hospital accommodation*, and the arrangements for securing a proper administration of hospitals, should not be overlooked.

In recent years, among the most interesting changes which have occurred in many countries, have been the changes arising out of the introduction of railways, steamboats, and other improved modes of locomotion; and especially the effects produced by bringing into profitable use large tracts of land previously waste, and in opening out new fields for the production of commodities.

Also, during recent years, the rapid increase of newspapers and other species of periodical writing deserves notice; and attention may be profitably directed to the state of the law relating to the press, and to the number, circulation, line, and general character of the leading periodical publications.

It is very desirable in collecting statistical information that the facts should be arranged as carefully as possible, and practically it will be found that, without attempting any refinements of arrangement, the effort to reduce the information into tabular forms will conduce to clearness and fulness.

In every country, having any claim to civilization, it will be possible to procure maps, and, by conversation with men of intelligence, the visitor may get to know the degree of reliance that is to be placed upon their accuracy.

The limited space that can be given in this volume to the subject of statistical inquiries has necessarily confined the recommendations which are offered to the more leading or important objects, which are also noticed with the utmost brevity. To persons of intelligence who visit other lands, many peculiarities will present themselves which they will think worth recording, although nothing may have been said concerning them in these pages. One caution it appears desirable to offer; it is, that no fact should be disregarded as without value by reason of the incompleteness of the information it yields, since it may well be that this very fact may supply a link in the chain that will give value and completeness to former or to future observations.

ARTICLE IX.

THIRD DIVISION, SECTION 3.

MEDICINE AND MEDICAL STATISTICS.

BY ALEXANDER BRYSON, ESQ., M.D., F.R.S.

As a large proportion of the naval force of this country is generally employed on foreign stations, it will necessarily happen that amongst the first things which will engage the attention of a medical officer are the effects produced on the constitution by a change of climate; and the question of the necessity or non-necessity of meeting this change by an alteration of personal habits or modes of living;—whether on entering the tropics it will be prudent to continue the use of the same daily amount of food, to lessen its quantity, or to adopt a diet less stimulant as regards fluids, and more farinaceous as regards solids. Different views have been adopted on this subject, some of them erroneous, others extravagant, or only feasible were the human body an inanimate machine; while there is a third and a more important class founded on experience, which are well worthy the attention of the scientific inquirer. Opportunities to simplify and reduce these into a more intelligible form will not be found wanting in the naval service.

In noting the meteoric changes which are likely to affect health, there are not, it may be assumed, any great difficulties to be encountered in making instrumental observation; mathematical precision, at all events, is not so essential as when the results aimed at depend on the truth of a series of arithmetical sums. Nevertheless, in the mere registration of this kind of formulæ, accuracy is required, as one omission may invalidate a whole set of observations,—such for example as the geographical position of the ship at the time the observations were made.

With regard to the atmosphere, the principal points to be observed are its heat, degree of humidity, and weight. That the two first greatly influence health there is no reason to doubt; but with regard to the third, it would be hazardous to offer any decided opinion. Amongst men who have devoted much time and attention to the subject there are perhaps a few who consider that at times it may have some influence on the mental functions. Thermometrical observations with the view of noticing the effect of atmospherical heat on health should be made several times a day, in order that the minimum, medium, and maximum in the shade may be ascertained; or even more frequently should there be a sudden rise or fall of the mercury. In a ship under-weigh it is hardly possible, in consequence of the great variety of aspects in which she may be placed with respect to the sun, and the various currents of air set in motion by her movements, to find a suitable place for the instrument; the black bulwarks and hammock-cloths rapidly absorb the heat of the sun's rays, and again throw it out by radiation for a considerable time after sunset. Should the instrument therefore be placed, as sometimes happens, contiguous to these, it will give an exaggerated view of the temperature. In the same manner the under surface of the deck radiates heat abundantly after the upper surface has been for some time exposed to the rays of the sun, consequently the temperature of the cabins and the space between-decks is sometimes greatly increased; this, if continuous, should be placed on record, as well as the influence it may be supposed to have on the general health of a ship's company. In connection with accumulated heat from these or other sources, it would also be proper to state the space allowed to each hammock, the number of hammocks berthed on one deck, and in a general way the dimensions of the deck, together with the size and disposition of the scuttles, ports, and windsails.

Acute inflammatory diseases and fevers have most unquestionably been induced by a current of external air rushing from the lower orifice of a windsail on men while asleep. Are we then to suppose, in the absence of all terrestrial miasmata, that these diseases are the result of the sudden abstraction of heat from the system? Simple immersion in the sea, or exposure to the external air in a state of nudity, has seldom an equally deleterious effect.

These, and subjects of a like nature, are well deserving the attention of every medical inquirer; for as yet there are but few of the doctrines respecting the origin of disease, or the manner in which the different forms of morbid action (when once established) progress, culminate, and decline, that are so clearly demonstrable as could be wished.

As a humid state of the atmosphere, particularly within the tropics, seems to exercise a considerable influence over the health of Europeans, hygrometrical observations are not less essential than thermometrical to a full investigation into the cause and nature of any of those diseases usually denominated climatorial. Various instruments have been used for these purposes; but those which denote with ordinary accuracy the state of the atmosphere, and are the least liable to go out of repair, are the best. It will naturally occur to the observer to guard against confounding the moisture arising from local causes, such as the damp state of the decks, or the halitus from the breath of a large body of men confined in a small space, with the natural moisture of the external air. Should the disparity, however, between the latter and the air between the decks on which the men generally congregate and sleep, be great, it will be incumbent on him when he uses an instrument to note the difference. From these data, viewed in connexion with the results of the thermometer, some better mode of ventilating vessels of war destined to remain for years within the humid regions of the tropics may be discovered.

To a dry air we are accustomed to attribute a bracing effect, to a moist air a relaxing; and there seems to be no reason to doubt the truth of the postulate; the first increases, and the second diminishes the amount of watery fluid in the system; the one as a general rule conduces to health, the other to disease. How far these conditions modify morbid action it would be desirable to ascertain. That intermittent and remittent fevers are peculiar to moist localities, experience amply proves; and although the subject yet requires to be more fully examined, facts are not wanting to lead to the supposition that dysentery, and diarrhœa approaching to dysentery, are more frequently the result of atmospheric changes in certain dry localities within the tropics, than they are in moist localities in similar parallels of latitude.

The relative degrees of health enjoyed in vessels differing in the hygrometrical condition of the air between decks, from whatever cause (exclusive of external causes) such differences may arise, is a subject which has long engaged the attention of all classes of naval officers; and although the majority are of opinion that a dry condition is the more healthy, still there are others practically acquainted with the subject who do not admit that the difference is appreciable, or who deny that damp decks have anything whatever to do with the health of a ship's company. As these conditions principally depend on the modes of cleaning the lower decks, it more especially belongs to the medical officers to watch with vigilance, and report (but not without due and ample experience) the effects of dampness, whether from accident, stress of weather, or artificially produced, as well as the effects of dryness artificially maintained by swinging stoves or other contrivances.

The marked difference in the appearance of men employed in the bread-room and holds, compared with those who are freely exposed on deck, or in open boats, at all hours of the day, cannot escape the notice of the most superficial observer. It is therefore of importance to ascertain whether exclusion from the solar rays be not, to a greater extent than is generally believed, one reason why men who have acquired a pale waxy look from confinement below are more susceptible to disease, and less capable of sustaining its shocks, than are those whose blood is enriched and strengthened by the free exposure to light, heat, and air. The force of these remarks, however, will be best understood by those who have had opportunities of witnessing the rapid change which takes place in the human constitution by exposure for only a short time to the direct rays of a tropical sun. Why, even in a state of perfect repose, the blood should acquire a brighter tinge, and an increased force of circulation, are inquiries, the value of which the observant physiologist will not fail to appreciate; neither will he fail, as often as opportunities occur, to follow up these phenomena, should they terminate in disease, or unhappily produce death.

Whether the average rate of the pulse is the same at great elevations above the sea-level as it is in those habitually resident *at* the sea-level has not yet been ascertained. In connexion with this subject, therefore, the following are the principal objects which deserve to be noted when opportunities occur of visiting places of great altitude:—the number of pulsations of the heart, and the number of times respiration is performed per minute; the circumference of the chest taken at the upper, middle, and lower thirds; the height, age, sex, and colour of the person examined, and whether in a standing or sitting posture at the time of examination.

The distance to which terrestrial miasmata may be borne by the external air has been so variously estimated, that correct information on the subject would tend not only to the benefit of the public service, but to the credit of the medical profession. In selecting a proper position for an encampment, or for the anchorage of vessels of war, the greatest discretion and judgment are required, particularly in those countries which abound in the aërial or telluric agencies inimical to man; and although these are matters on which the medical officer is not invariably consulted, and although necessity and the exigencies of the service may render the selection of the worst localities inevitable, still, dreading the suffering and loss of life which may be occasioned by a position badly chosen, the external geological features of any coast or island off which a squadron may require to be concentrated cannot fail to attract his attention.

In connexion with terrestrial emanations, atmospherical currents depending on local causes, together with a description of land and sea breezes, are also subjects deeply interesting to all classes of men, whether employed in her Majesty's naval service, or otherwise engaged in maritime pursuits. It is, therefore, much to be desired that the country contiguous to any unfrequented creek or bay, or the embouchures of tidal rivers which are likely to become the resort of shipping, should be examined, and, if found to contain lagoons or marshes, mapped so that those spots which are the most exposed to malarial currents may be known, and if possible avoided. The nature of the soil in the immediate neighbourhood, the kind and the depth of water in lagoons, the character, depth, and consistence of swamp, bog, or marsh land, the description of plants which surround or grow from them, would greatly enhance the value of such information. These being the acknowledged sources of fever and ague, it would not escape the zeal of the inquirer to ascertain whether they were liable to irruptions from the sea, or floods from the interior; whether fogs arose from them, and if so, at what time of the day or year they were most observable; and also whether they emitted noxious effluvia. Officers and men employed on boat service on the west coast of Africa have sometimes discovered within the mouths of tidal rivers particular places in which noxious effluvia were much more perceptible than in others.

There are few things of more importance to the naval medical officer than the origin and character of febrile diseases, as a knowledge of the facts connected with the former may greatly bias his judgment with regard to the latter; and as the expression of his opinion thus influenced or formed, particularly with regard to their being of an infectious or of a non-infectious character, may endanger not only the health and the lives of the men in his own vessel, but the health and lives of men in other vessels, and even in communities residing on shore, it will be admitted that these are not subjects, when opportunities occur, that ought to be superficially examined or inattentively reported.

Besides endemic and epidemic fevers which arise from general or terrestrial sources extraneous to a ship, there are others which originate in local or personal causes existing on board. To distinguish between these is a matter of greater difficulty than seems to be generally apprehended. For instance, fever may break out in a single vessel of a squadron, and attack not only the whole or the greater part of her crew, but visitors, though they remain on board for a few hours only. If these latter, after returning to their own ship or home, pass through the disease without communicating it to any other person, the opinion generally formed has been, that the fever was the result of exposure to some local cause unconnected with the emanations from the sick; but if in either case the attendants or immediate neighbours of the visitors were subsequently, within two or three weeks, seized with fever similar to that of the latter and of the patients in the ship, and again other persons who had been in close communication with them were attacked, then the conclusion arrived at has been (as indeed it could not be otherwise) that, if it were not originally contagious, the disease had acquired in the course of its progress the power of propagating itself, and that in all probability it would through a series of subjects retain that power for an indefinite time. But even admitting that the origin of the fever may be clearly traced to some cause within the ship, it will yet remain to be determined whether that was of a local or of a personal nature, or of some peculiar combination of the two. In many cases it most unquestionably will be difficult, if not impossible, to decide; nevertheless, a concise narrative of the events as they occur should be committed to paper, in order that it may be made available, should it be required for any investigation in connexion with the reappearance of the fever at a future period either in the same or in a different locality.

When a fever has broken out in a vessel at sea, from a foul state of her holds, and continues to make progress, attacking man after man, how, it may be asked, is it possible to ascertain whether it has acquired a contagious character or not? The space is small, and the whole of the men being equally exposed to the original exciting cause, and, if such has been generated, to the personal also, are there any means of distinguishing the effects of the one from those of the other, with that degree of certainty which would warrant the medical officer giving a conscientious opinion, if required by the arrival of the vessel in a port? The great similarity of all continued and remittent fevers, from whatever source they may arise, and the utter impossibility of complete segregation, even in the most roomy vessel, will, it is apprehended, render it extremely difficult to make such a distinction; and the delivery of any opinion beyond that which may be hypothetically formed impracticable. Still, on the appearance of any epidemic in a ship of war, it will be necessary to come to some determination as to its origin; for on this will depend the propriety of removing the cause, or removing from the cause, viz. clearing out the vessel or quitting the locality. If it arise from causes within the vessel, these should be stated, and also the means taken to remove them; if from causes extraneous to the ship, they also, if possible, should be described, as well as the manner in which the men were exposed to their influence. The treatment of the disease will naturally rivet the attention to the symptoms; these again should lead to a more useful nosography than is generally adopted; the disease being placed under one of the three following distinctive heads, viz., continued, remittent, or intermittent. This, however, should it be deemed of importance, need not prevent the annexation of any qualifying or explanatory distinction, such as bilious, ardent, or yellow; and, to reconcile the conflicting opinions which prevail respecting tropical fever, proof of the absence or presence of remissions, in some of its worst forms, may still be considered necessary.

As long as there is a British squadron on the sea, yellow-fever, as it is called, must claim a large share of attention; and as it is seldom brought to these shores, he who encounters it on its own domain will do well, while it is under his eye, to examine carefully into its origin and character. When it occurs as an epidemic its source should be looked for, its course traced, and its disappearance noted; and whether yellow suffusion be present in all the cases, or only in part of them; whether, when black vomit occurs, the disease acquires a greater degree of virulence; and whether, in consequence of such aggravation, marked by deep yellow suffusion, dark-coloured blood, hæmorrhage, and, in the fatal cases, black vomit, it becomes more contagious. As it does not appear by the records in the office of the Director-General, that yellow fever ever broke out in a ship of war, unless she communicated with an infected ship, or entered a port where it was, or recently had been prevalent; as there is no trustworthy evidence to show that it has ever broken out spontaneously in any locality on shore; and as it has never yet been observed throughout the tropical regions of India, along the eastern coast of Africa, or in any island, with the exception of Ascension, north of the equator, any information respecting the spontaneous origin of a disease so fatal would be highly interesting.

Whether the common remitting fever of the tropics has ever changed or degenerated into true yellow fever is a question on which medical authorities are still at issue, although the non-appearance of the latter on the swampy shores of Zanzibar, in India, Malacca, Borneo, and China, on the broad swamps which bound the Niger, where the worst forms of remitting fever prevail, would lead to the inference that these two diseases depend on totally different causes.

Whether the yellow suffusion depends on a broken-down condition of the blood, or on the absorption of bile into the system, has not yet been determined. Two pieces of skin taken from the same body were recently examined by two of the most eminent physiologists in London; one thought the yellow colour was due to altered blood, though there was no evidence to prove the absence of bile; the other thought that the colouring matter was derived from bile, and that, "curious enough, it was chiefly seated in the epidermis and epithelium of the segmentary follicles." Here then, particularly if taken in connexion with the remedial measures which would require to be adopted were either of these conditions established, is a wide field for inquiry and observation.

In the treatment of yellow fever there is most assuredly much to observe, and much to learn. The effects of the most vaunted remedies should be watched and compared. Blood-letting, and the nature of the blood abstracted, offer a fair field for observation, whilst the empirical modes in which we have been taught to exhibit mercury will perhaps induce the younger physician, when he begins to think for himself, to reinvestigate the grounds on which his seniors recommended these questionable practices, and to compare them with the results obtained in the present day. Though quinine, or quinine wine, as it is now employed in the naval service, has been found to be extremely useful in preventing the evolution of periodic fevers, there is no reason to suppose it will prove equally efficacious in preventing yellow fever.

Pathological investigations have thrown but little light on the nature of simple idiopathic fever. To detect the seat of the disease, or to ascertain the cause of death, the solids have been explored in vain; the vital organs of the head, the thorax, and the abdomen, have each refused to reveal why they gave up their functions: to the fluids, therefore, armed with the additional powers which the science of optics affords, and with a better knowledge of animal chemistry, we must resort. The blood, in connexion with respiration, will require to be examined to ascertain whether the functional derangement which exists in the organs of sanguification and respiration, in the first instance, be the effect of a chemical change in the blood; or whether, as some have supposed, it be the result of an impression made on the nervous system by some power or agent exterior to the body; and whether such derangement of action, by whatever means established, interrupts the normal transfer of elementary principles between the external air and the blood, thereby leaving the blood so greatly altered and deteriorated as to be chemically defective in those constituents requisite for the repair of the organic structures, while it abounds in the lethal effete matters that are constantly passing into it from the decay of the latter.

In the Naval service, more frequently perhaps than in any other, there are opportunities of ascertaining to a day, and even to an hour, the exact period of incubation in certain endemic and contagious diseases. A number of men, a boat's crew for instance, may enter a vessel, a house, or a village in which a contagious disease is raging; or they may land, expose themselves to the influence of a "homicidal marsh," and then return on board, having inhaled a sufficiency of the poison to establish a certain specific morbid action, bearing, if of a personal nature, the exact similitude of its parent; and if of a terrestrial, that type of fever peculiar to the climate or locality, or to the prevailing epidemic—it will of course follow that, in proportion to the length of time the patients have been exposed to the exciting miasm, so in an inverse degree will be the value of the information, as during a protracted exposure there is no means of even approximately ascertaining when the system had acquired the requisite charge necessary to the evolution of the disease. The latent period of endemic fevers is a subject which is both curious and interesting; but with regard to contagious diseases it is infinitely more so, as it is principally on a correct knowledge of these periods that the quarantine laws can be efficiently administered.

Exanthematous diseases are still an interesting study: information respecting their incubative periods, as well as information relative to the time the exciting poison of each will retain its specific action after it has escaped from the body; proof of their spontaneous origin where communication with an infectious source was impossible, would, in connection with their total extinction, also be of value. Happily there are few who do not believe in the communicability of these maladies, but of late attempts have been made to depreciate the great boon conferred on mankind by the discovery of the immortal Jenner. It has been stated, but on what grounds it would be difficult to discover, that vaccination has rendered the population more susceptible to other diseases, or, in other words, when small-pox is prevented or forestalled by cow-pox, that a large amount of rudimental disease is left in the system, which ultimately explodes in various other forms of morbid action. Evidence for or against these novel doctrines should not be permitted to pass unnoticed. Second attacks should be placed on record, and the medical officer ought not to omit mentioning whether the patient attacked with small-pox had or had not been vaccinated.

Of all the diseases which attack the human race there is not one respecting which sound information ought at the present moment to be more coveted than Asiatic cholera, for, although its infectious character is now pretty generally admitted, still there are many who deny that it possesses this property, and vainly endeavour to trace its origin and spread to accumulations of filth, to peculiar states of the weather, to changes in the atmosphere, and to various other causes which have no existence but in their own fertile imaginations. As cholera, like yellow fever, has never made its appearance in any locality, either in this country or in America, unless there had been communication with some other locality where it did exist; any apparently isolated outbreak of this disease should be carefully examined. Its incubative period,—the time which the infectious germs when separated from their source will retain their productiveness,—whether they adhere to inanimate substances,—and whether secondary attacks of cholera are frequent, or whether one attack renders a person less liable to a second, are all questions of vital importance.

The incubative period of plague, and, if it rage epidemically, proof of its having been transmitted from one person to another, either simply through the medium of the atmosphere, or by means of fomites, are still questions of paramount interest to every nation which has any communication with the shores of the Méditerranean.

To the medical officers of the army and navy we must look for information relative to the geographical distribution of diseases. Why yellow fever has been gradually extending within the last few years along the east and west coasts of South America, one of the most healthy regions in the world, and why cholera has not yet reached the western coast of Africa, one of the most unhealthy regions in the world, are questions that will be answered differently by different persons according as they believe in their infectious or non-infectious character. To mark, therefore, the introduction and the progress of these two maladies over regions where they are still unknown, is the bounden duty of every man who has the welfare of the human race at heart. Information relative to the cause or origin of endemic maladies is also much required. Why, for instance, Europeans suffer so much from bowel complaints on the coast of China, and not on the west coast of Africa; why on the former they should be infested with intestinal round worms, and on the latter with tape worms; why the dracanculus should be met with on the west coast of Africa and the chigre in the West Indies, we are unable to explain; but, by patient investigation, and by following the paths where science leads, we may yet hope to discover many of nature's hidden secrets.

Some curious information may be obtained in distant countries relative to the modes of treating diseases amongst uncivilised tribes; not that it is likely to prove of much value, but as a matter of history it may be worth recording. It would even be interesting to know the virtues attached to charms and amulets, as well as the manner in which they are obtained, of what they consist, and how they are worn; nor would the methods of performing surgical operations be of less interest. The Albanians, it is reported, with but slight knowledge of anatomy, perform the operation of lithotomy with dexterity and success. The Marabouts of Africa, with a fallen tree for their table, may be seen, with little display, performing the initiatory rites of Mahomedanism on the assembled youths of an entire village; while the Fetish man, on another part of the continent, ministering to the pride of caste, makes such fearful gashes on the cheeks of his patients as would astonish our boldest practitioners. How these wounds are cured might be worth knowing, as the scars sufficiently attest the excellence of the surgery.

In the central parts of Africa, and in some of the islands of the Indian Archipelago, there is reason to believe that the natives are in possession of narcotic poisons with which we are still unacquainted. An account of these, and of the modes in which they are prepared, would be interesting. And on all occasions the diseases most prevalent in the various foreign countries visited, and the most approved methods of treating them, together with an account of the medicinal plants, and other means in general use as remedies, should in conformity with the public instructions be invariably reported.

In preserving medical plants or seeds, and other objects of natural history, for the purpose of bringing them to this country, it will be found no easy matter to protect them from the ravages of insects, and in damp countries from the effects of mildew. The tin cases now used for certain articles of dress are well adapted for the safe keeping of perishable substances; but when they cannot be procured, a deal box made to fit snugly between the beams of the small cabins allotted to gun-room officers, with its seams closed up by pasting paper inside, is the best substitute. From these predatory insects may be excluded by scattering amongst the contents pieces of camphor, and rags sprinkled with turpentine, to which a few drops of the oil of petroleum will be a useful addition. Into a box so protected neither ants nor cockroaches will enter; and without some contrivance of the kind it will be in vain to attempt to preserve almost any object of natural history of an animal or vegetable substance; unless it be placed in spirits or in a dilute solution of the chloride of zinc. The latter, as it is now generally employed in ships of war for the destruction of vermin and the prevention of fetid exhalations from the holds, is not only the most available, but in other respects it is perhaps the cheapest and the most generally useful. It has been successfully used by the curator of the Museum at Haslar, in the proportion of one part of the concentrated solution to twenty of water, for preserving fish and reptiles, and, when in good condition, specimens of morbid anatomy; but when the latter are very putrid they require at first a much stronger mixture, namely, about equal parts of each. In this the preparation is allowed to remain until it is free from smell, when it may be finally put up in a solution of the first-mentioned strength.

In the first edition of the Admiralty Manual of Scientific Enquiry several suggestions were made with reference to the improvement of the medical returns, which have since been adopted, so that the statistical information required is now more available, and it is to be presumed more correct, than it was formerly; still there is room for improvement.

In each surgeon's journal there are two statistical tables: in one all the cases of disease and injury from the day the ship was commissioned up to the 31st of December are to be included; the other is to be used only when the ship is paid off or when the surgeon is superseded, and when his journal contains part of two years. It may thus happen that the surgeon begins his journal in July and ends it about the same time in the following year; nevertheless the table should include the cases only which occurred during the first year, and the additional table may be left blank; but the first table in the following journal ought necessarily to contain all the cases which occurred between the 1st of January and the 31st of December. The propriety of closing the statistical table on the 31st of December does not appear to be generally understood, but this is absolutely necessary in order that the health of one part of the force may be compared with another for corresponding periods and seasons. A statistical table which contains part of two years is useless.

The number of days each case remained under treatment being given, the total loss of service from disease and injury may be readily ascertained. As, however, a few sickly men in a ship may increase the aggregate number of days' sickness, it would add to the value of the returns if the medical officer would notice in his sick-book and in the annual statistical return the total number of secondary entries for the same disease, and the total number of men whose names were not entered on the sick-list during the period. Ten cases of ague, for instance, may be reported in the Nosological Return, though one person only suffered from the complaint. And with the view of still farther following out the influence of climate and locality on European life, it would be desirable were the medical officers to mention, in their lists of men dead and invalided, where the disease in each case was originally contracted, as it frequently happens that men die on one station of a disease contracted on another.

When a case, from an error in diagnosis, has been entered in the sick-book under a wrong name, or when the original disease is displaced by one of a more important character, the first insertion should be scratched out, and the disease which decides the fate of the patient, whether by death or invaliding, written under it. Many fatal cases of dysentery and cholera make their appearance in the form of diarrhœa, but it would be highly incorrect to report the deaths under that head. On the other hand, death may result from disease consequent on an injury or on another disease; for example, a man may die of paralysis arising from fracture of the spinal column, or of gangrene consequent on erysipelas: in these and similar instances the death should in the first case be put down to the injury, and in the second to the primary disease, and not to diseases of a secondary, or of a consequential nature. Still there are cases in which the changes may be so imperceptible, and in which the links which bind causes and effects together are so obscure, that it will be difficult, if not impossible, to decide under which head the death ought to be placed. The surgeon in these and in many other instances must be guided by his own judgment.

ARTICLE X.

THIRD DIVISION, SECTION 4.

ETHNOLOGY.

BY THE LATE J. C. PRICHARD, ESQ., M.D.

[*Revised by* T. WRIGHT, Esq., *and* Monsieur D'AVEZAC, *on the part of the Ethnological Society.*]

THERE are few subjects that can engage the attention of intelligent travellers, more worthy of interest, or on which any additions to our previous stock of information will be more generally appreciated, than ethnology. Under that term is comprised all that relates to human beings, whether regarded as individuals or as members of families or communities. The former head includes the physical history of man; that is, an account of the peculiarities of his bodily form and constitution, as they are displayed in different tribes, and under different circumstances of climate, local situation, clothing, nutrition, and under the various conditions which are supposed to occasion diversities of organic developement. The same expression may also, in a wide sense, comprehend all observations tending to illustrate psychology, or the history of the intellectual and moral faculties, the sentiments, feelings, acquired habits, and natural propensities. To the second division of this general subject, viz. to the history of man as a social being, must be referred all observations as to the progress of men in arts and civilization in different countries, their laws and customs, institutions—civil and religious their acquirements and traditions, literature, poetry, music, agriculture, trade and commerce, navigation; and, which of all things affords the most important aids in all researches as to the origin and affinities of different tribes or races, their languages and dialects.

On almost every topic now enumerated our acquaintance with remote nations is at present much more extensive than it was a quarter of a century ago; but on all it is still very defective. We shall touch upon the different subjects of this investigation in a very brief manner, with a view to point out what remains to be done in each particular, and to offer some suggestions as to the best method of proceeding.

I. *Of the Physical Characters of Nations.*

The physical description of any tribe or race must commence with an account of the more striking and obvious characteristics of complexion, features, figure, and stature.

In reference to the *complexion or colour*, it is not enough to know generally whether it is black, or white, or brown. The exact shade of colour should be described as it prevails in the majority of persons in any tribe, and all the variations should be noted which occur in individuals. If a great difference of colour should be observed in the people of the same community, care should be taken, by repeated inquiries, to ascertain, if possible, whether such diversities are merely accidental varieties, or are connected with any distinction of tribe or caste. In many countries tribes exist who, while they preserve their stock distinct by avoiding intermarriages, continue to differ from each other in colour and other particulars, though in other instances great varieties are observed within the limits of the same race, which appear as if they were capricious and accidental deviations, analogous to those varieties which appear in cattle and other domestic animals. A careful inquiry as to the history of individuals and families will sometimes determine how far the phenomena alluded to may be referable to either of these observations.

The *shape of the features* and the form and expression of the countenance should be described. For this purpose words afford but very imperfect means of communicating correct ideas. It will be advisable in all instances to obtain, if possible, correct portraits of persons of both sexes, and these should be coloured so as to represent the complexion as well as the form of the countenance. If no artist should be present who is capable of taking a likeness, the form of the features may at least be described by a profile or shaded outline. The use of photography, however, now affords a great facility for effecting this object.

The *colour of the eyes* should be noted, as well as the direction of the eyebrows: whether oblique, as in the Chinese and some Tartar races, and standing upwards towards the temples, or straight and parallel to the axes of the orbits, as in most European heads.

The *hair*, whether woolly and crisp, or curled and wavy, or straight and flowing, should be described, and specimens obtained of it. Notice should be taken of any varieties of the hair which occur in any particular tribe, there being great varieties in the nature of the hair in some races, while in others it is nearly uniform. Its colour should also be remarked.

An account should be taken of the average *stature and weight* in both sexes. This can only be obtained by the actual measurement and weighing of a considerable number of individuals, and the number and extent of the measurements should be mentioned. The proportional stature of the different sexes differing in different races, an account should be taken of this fact. Extreme cases should be noticed.

The proportion between the length of the limbs and the sternum, and the height of the body and the breadth of the pelvis, should be ascertained, and the length of the forearm in proportion to the stature of the body. This is known to be much greater in some races than in others.

Particular attention should be paid to the *shape and relative size of the head*, since this forms one of the principal characters distinguishing the several tribes of the human family from each other. The most authentic testimony in regard to this particular, and one which will be very acceptable to scientific men in this country, will be afforded by bringing home a collection of skulls, if they can be procured. In that case it would be necessary to select those skulls for specimens which afford the best idea of the prevailing form of the head in the particular tribe; and, if several forms are observed in any race of people, which is the case in some islands of the Pacific Ocean, specimens should be sought which serve to identify every leading variety. If skulls cannot be procured, the best substitute will be casts of heads. Failing these, it will be requisite to take measurements. Such measurements should state the proportion between the longitudinal and transverse diameters of the skull, which will show whether the skulls of the tribe belong to the elongated form or to a rounder one. The facial angle may also be taken, formed by two lines, one of which falls from the forehead slanting over the edge of the upper jaw-bone, and the other passing from the meatus auditorius to the basis of the nose. The breadth of the face should also be taken by measuring the space between the zygomatic arches. In well-formed heads of the European type, the lateral surfaces of the zygomatic arches are parallel to the temples or the lateral surface of the frontal bone; so that the breadth of the forehead above the eyes is equal to the breadth of the face from cheek-bone to cheek-bone, measured by a line passing across the bridge of the nose. But, in the Turanian type, common to the Chinese, Mongolians, and other nations of High Asia, the forehead is so much more narrow than the face as to give the upper part of the head almost a pyramidal form. An account should be taken of these characteristics, which most obviously distinguish the High Asiatic from the European type, and likewise of the extent of the upper and lower jaws, an excess of which is the chief peculiarity in the head of the Negro, and of other races approaching the Negro type. The oval, pyramidal, and prognathous types, as above described, constitute the three leading varieties in the form of the human head, but, together with the description of these characters, notice should be taken of every peculiarity that can be detected on a careful inspection of the cranium, or of the heads of living persons, when skulls cannot be obtained.

Attention should also be paid to any artificial means employed to modify the natural structure of the skull, either by the use of bandages which have the effect of lengthening it, or of applications for depressing it in certain parts.

Observations on the *form and structure of the body* should be followed by inquiries which belong to the department of physiology, which includes all that relates to the functions of life. Under this head we must mention inquiries respecting the senses or sensorial faculties. It is well known that there are differences between the different tribes of men in regard to the perfection of these faculties, and that some of the nomadic nations of High Asia, for example, have a remarkably acute sight and hearing, while other nations are equally noted for the perfection of taste and smell. Observations on these particulars belong to the physical character of each tribe.

Attempts should likewise be made to obtain information as to the relative degrees of *muscular strength* in various races. An instrument invented for this purpose has been termed the dynamometer. If it should not be at hand, the same purpose may be answered by experiments showing what weights a given number of men can raise by their individual efforts.

Other physiological characteristics should be investigated when opportunity can be found of obtaining information that may be satisfactory respecting them: such are the average length of life in any tribe; the ages of puberty and of the cessation of child-bearing, and all other facts connected with the animal economy, such as the number of children in families. Various questions have been raised by physiologists as to the phenomena connected with the functions of the female, whether they are subject to similar laws in the different races of human beings; and, although, generally speaking, the result of such inquiries has been to show that no important difference exists, it is still right to pursue the inquiry in regard to newly discovered tribes, whenever opportunity is afforded by the accidental residence of medical persons in any place, or other contingent causes may promise to afford accurate results.

Pathological observations are nearly connected with physiology. It behoves the traveller to collect whatever information he can acquire as to the diseases prevalent in any tribe of people, or among the inhabitants of any country which it is his fortune to explore.

II. *Characteristics of the State of Society, &c.*

Questions which have regard to men in their social state, or as members of tribes or communities, take a much wider scope than the personal history of individuals. The ordinary habits of life and the modes of obtaining subsistence are the first topics that present themselves when we proceed to this branch of the subject. The rudest or most simple stage of human society is not without its appropriate arts. Some of these indicate as much enterprise and ingenuity, and as great activity of the intellectual faculties, as the practices of more civilized men. People who subsist on the spontaneous fruits of the earth, without pasture of cattle or cultivation of the soil, must exercise great ability in merely obtaining the means of subsistence. This is called the hunting state. It is not always a primitive condition of men. The history of the South African nations proves that tribes of people may sink into it from a higher state. The Bushmen once resembled the pastoral Hottentots; and even the African bushmen, as well as the Australian savages and the most destitute of the Esquimaux and other American tribes, display as much ingenuity in following their respective pursuits as nations of much more refined and artificial habits of life. The arts and customs of nations in this state form an interesting chapter in the history of mankind and in the ethnography of particular branches of the human family.

Races inhabiting high steppes and open plains, such as Great Tartary and the plateau of Southern Africa, are generally nomadic herdsmen. Their habits of life are very different from those of the hunting tribes, and many of them differ from the latter in physical organization. The pastoral nations, wandering through open plains and enjoying a life of leisure and contemplation, have cultivated astronomy and a simple kind of poetry. Their history presents features of great interest to those who have opportunities of observing them.

Some of the rude and hunting nations have practised agriculture to a limited extent, but this pursuit is precluded by the locomotive habits of the nomadic nations. The indolence of savages generally throws this labour, as is well known, on the females of the tribe. In this state of things hunting continues to be the main occupation, and the habits of the tribe are not greatly changed by the introduction of a scanty tillage. But when the cultivation of the soil becomes the chief means of subsistence, the people must cease to be hunters or wandering herdsmen; they become fixed on particular spots, and separated into small communities. Hence agricultural tribes differ from each other in language, and likewise in physical characters, more than the nomadic races. It is highly desirable to inquire in every country into the facts connected with this transition, and to observe how far the introduction of agricultural habits has been connected with agrestic slavery. The change from the free and wandering life of pastoral nomades to the toilsome drudgery of the agriculturist is so great a change that it has probably never taken place except under circumstances of peculiar kind. The earliest agriculture of most countries appears to have been connected with slavery. In many places there were "adstricti glebæ," who performed the laborious part. In many instances these were a conquered people reduced to the condition of serfs. Such were the Sudras of India conquered by the twice-born classes. The Helots of the Spartans, and perhaps the γεωργοι of the Egyptians, were the descendants of captives. In every country where the soil is cultivated, as it often is, by a particular tribe, it will be advisable to make accurate inquiries into the history of such races. In these the traveller will often find the descendants of aboriginal inhabitants, the genuine people of the land, and among them he will discover the ancient and primitive language of the country, while the lords or feudal masters of the soil, the dominant people, will be found to be merely late immigrants from some foreign country.

The methods of agriculture anywhere practised should be noted, as well as the kinds of grain which are found to be in use. The whole of the esculent plants used by any tribe of people should be described. Few races of men, however rude and insulated from the rest of mankind, have been found without some exotic vegetables. It has been observed that there is scarcely a hamlet in the most inclement parts of Lapland where some garden-plant may not be discovered which has been imported from places of more genial climate. The esculent plants in the possession of any remote and secluded people may often afford a clue as to the origin and family relations of the tribe.

Light also has been thrown on this subject by the kinds of instruments used in agricultural works. Notice should be taken of the forms of the plough and of the different instruments used in tillage, and of the peculiar methods of cultivation anywhere found to be in use.

The mechanical arts practised by various nations are to be carefully observed, such as their preparation of clothing, their architecture, or the manner in which they construct their dwellings and their household furniture.

A subject worthy of particular inquiry is their metallurgy, and the degrees of skill displayed in the arts of mining and making metallic implements. Many rude nations are known to have had some knowledge of the precious metals gold and silver, and even to have smelted copper long before they learned to know the use of iron. Various ornaments of silver and gold are found in the tombs of many northern nations, who are supposed to have been too rude to invent the manufacture of steel, and who perhaps never dug the iron ore which abounded in their own mountains. In many countries we trace the remains of a barbarous age, when cutting implements of various kinds were made of flint or stone, and when even ornaments were manufactured from bone, or amber, or ivory, before the use of metals was discovered. The names given to metals should be noted, since these names will often afford a clue as to the countries from which they were imported.*

The art of war, as practised by various nations, affords a wide field of observation. The weapons used, whether bows and arrows, spears, or clubs, or swords, are often common to scattered tribes of the same kindred, and will serve to identify nations, or at least to suggest inquiries as to the probability of their relationship. The ancient Gauls were known by their gæsa or javelins, the Germans by their saga or military cassocks, and the Australians by their woomerangs or throwing-sticks, while the poisoned arrows of the Bushmen are noted among the South African nations.

The sort of clothing used by simple nations, as well as that of the more cultivated, should be described †—whether made of the skins of animals, as among the most savage nations, and especially those of arctic countries, or of cloth prepared by weaving, or otherwise preparing the fibrous parts of plants, as cotton, flax, or other vegetable productions. Attention should be paid to the modes of cultivating such plants as contribute the material of clothing.*

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* Thus it has been observed that the Greek name for tin, "κασσιτερον," resembles the Indian (Sanscrit) name (Kast'hered) of the same metal, and it has been inferred that tin was first brought to Europe from India before the British mines were explored. The tin-mines of Tama-Malaga, or Malucca, were celebrated at a very early period.

† Where the practice of tattooing prevails, particular attention should be given to its characteristic styles and difference of forms, as it may be regarded in some degree as the heraldry of savage nations.

In every newly-discovered country it will be an interesting subject of inquiry, what domesticated animals are in the possession of the natives—where they obtained such as they are found to possess—whether they are known as wild animals of the same region, or were brought from some foreign land.

Inquiry should be made as to the art of navigation practised by different races. Some nations appear to have a greater aptitude for maritime pursuits than others. The Polynesians in some places are almost amphibious, while the American natives and the Australians rarely venture upon the sea. Several South American nations are, however, expert navigators in their inland lakes and vast rivers.

The crude notions entertained by uncivilized nations on subjects within the scope of physical science are matters worthy of inquiry. Science they can be hardly said to possess, though this was scarcely true with the ancient Mexicans. All nations observe the changes of the moon, and measure the lapse of time with a greater or less degree of accuracy by the movements of some of the heavenly bodies. Inquiry should be made whether the motions of the planets are observed, and whether these bodies are distinguished from fixed stars; whether attempts are made to ascertain the duration of the solar year, and whether there are names for the constellations, and what they are if they exist.

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* A curious mistake was made by the ancients in regard to silk. They imagined that it was prepared from beautiful flowers.

"For clothes the barbarous tribes of Seres use,
Nor oxen hides, nor wool of fatted ewes;
They weave sweet flow'rets of the desert earth,
Of finest texture and of richest worth—
Robes bright of hue as flowers which deck the mead,
Of finer texture than the spider's thread."

Dionys. Perieg. 755.

In every nation, however barbarous, it is probable that some sort of morality exists in the sentiments of men—some notions of right and wrong—and that some practices are considered lawful and praiseworthy, while others are forbidden. The same religious impressions and the same superstitions prevail through all the branches of a widely spread race, as the superstition of the *tabú* among the Polynesians. Inquiry should be made as to all traits of this description, and all the phenomena which enter into the psychological character of a particular tribe. Among these traits are the regulations respecting marriages in different communities. In some countries a complicated, and, as it appears, a very elaborate and artificial system of rules prevails, founded on the intention of preventing intermarriages between families even remotely connected by consanguinity. The institution of the *Totem*, as it was termed among the North American nations, has its counterpart among the nations of Australia. Whether the existence of customs so similar among these widely-separated races is a result of former intercourse, or a merely accidental coincidence, it is unnecessary to inquire. In both countries it constitutes a remarkable trait in the social and moral character of the nations among whom it prevails, and it may lead us to believe that nations apparently the most savage and destitute are not always governed merely by accidental impulses and animal passions, but are capable of deep thoughts and reflection, and of enacting laws with a wise and well-understood import.

Inquiries should be made as to all the regulations of social life, not only among civilized nations and those who are possessed of the external appearances of civilization, wealth, and conveniences, but likewise among people less prosperous in their condition, and having the aspect of barbarism.

Where polygamy prevails, it should be ascertained, if possible, whether there is any real disproportion in the numbers of the sexes. This should, indeed, be a subject of inquiry in every tribe where statistical information can be procured, as a matter connected with the physical history of the people; but it has a particular relation to the prevalence of polygamy.

The mode of civil government should everywhere be a subject of inquiry. The more simple nations are often without any common and central government, and are in the habit of only appointing a leader in time of war, when they select for some temporary enterprise as their chieftain some individual whose fame and prowess inspire them with confidence in his guidance. Some nations have been entirely without the idea of combining for mutual aid, and the Finnish races are said to have been conquered by the Germanic nations piecemeal, one family after another falling under the yoke, till all were subdued. The Polynesian nations have princes or chieftains, according to some well-understood laws. We are not yet acquainted with the social institutions of the Papuas, if they have any such among them, which is probable. It is very desirable that the fact should be ascertained by inquiry.

The religious impressions and the superstitious practices of every tribe of men should be carefully investigated, as forming a remarkable part of the history of the particular people, and an item in the psychological history of mankind. It is probable that no human race is destitute of some belief, more or less explicit or obscure, in the existence of supernatural powers, good and evil, and likewise of a future and invisible state. But there are nations who scarcely recognise in the invisible being anything like will or power to punish the guilty or reward the good, and who do not suppose the future state to be a scene of retribution. This is the account which missionaries and other persons have given of the Polynesian superstitions.

The adoration of rude nations is generally directed towards visible objects. From this remark we must except most of the American nations, who are said to believe in the existence of a spiritual ruler of the universe. By one class of rude nations the heavenly bodies are worshipped, and the

Polynesians connect this superstition with a mythology which is poetical and not devoid of ingenuity. Others, like the African nations, worship *fetiches*, or visible objects, in which they suppose some magical or supernatural power to be concealed, capable of exercising an influence on their destiny and of ensuring success in any undertaking—a superstition of which traces are to be discovered among the vulgar in many countries. In all instances it is important to note the names given to gods or to other objects of worship, as well as those given to the priests, as these may put us on the trace of the ways of civilization.

In every tribe of people among whom intelligent travellers may hereafter be thrown, it should be a subject of inquiry how far any of these observations may be confirmed and extended by the history of their superstitious belief and practices, and to what division of nations they are by such traits associated.

III. *Language, Poetry, Literature.*

As no other means have contributed so much to the increase of ethnology, and to the ascertaining of the connexions and relationship of different nations, as a comparison of languages, great care should be taken in every newly-discovered country, and among tribes whose history is not perfectly known, to collect the most correct information as to the language of the people.

Among tribes of people who have any poetry or other literature, pains should be taken to obtain the best specimens of composition in their languages. Manuscripts in their languages should be procured if it can possibly be done; and it would be worth while to incur even a considerable expense rather than forego such an opportunity.

In countries where the inhabitants have no knowledge of letters, it may sometimes be found that they have preserved oral compositions, generally in some sort of verse, which they have recorded in their memory, and handed down from one generation to another. It would be very desirable in such a case to write down the most complete specimen of any such pieces, and to select any which relate to the ancient and primeval history of the people.

If no literature or compositions of any kind have been preserved, the best things that can be done will be the following:—

I. To get some intelligent person to translate into the prevailing language some continuous composition, and to copy it from his mouth with the greatest care. Get in the first place the Lord's Prayer, since this same composition has been most frequently collected already, and exists in a much greater number of languages than any other. Next to the Lord's Prayer, which does not contain a sufficient quantity of words, the Gospel of St. Luke probably exists in a greater number of languages than any other composition. The sixth, and perhaps also the seventh chapter, may be selected from this Gospel. A good translation of these two chapters will enable a person skilled in philology to furnish a tolerably complete analysis of almost any language.

II. A vocabulary should also be taken down from the mouths of intelligent natives. Care should be taken to compare the words given by one person with the testimony of others, in order to correct any defect or peculiarity of pronunciation.

It is very important to select properly the classes of words. The following should be chosen:—

1. The numerals up to a hundred or more. Ascertain how far the people of each tribe can reckon.
2. Words denoting family relations, such as father, mother, brother, sister, &c.
3. Names of the different parts of the body—head, arm, foot, &c.
4. Names of visible natural objects, elements, &c.—sun, moon, fire, water, &c.
5. Names of animals, especially domestic animals.
6. Verbs expressive of universal bodily acts, such as eat, drink, walk, sleep, see, hear, &c.
7. Personal pronouns—I, thou, he, &c.

8. Prepositions—in, from, to, &c.—if they can be obtained.

III. It would be useful, in the third place, to observe some of the grammatical rules of the language, if opportunity exists of becoming acquainted with them; though, if any composition of some length shall have been obtained, the grammatical analysis may be furnished afterwards. It will not, however, be amiss to make the following observations:—

One great feature in the grammatical structure of different languages, which distinguishes several classes of languages from each other, is the peculiar position given to auxiliary words in sentences. By auxiliary words are meant such words as have no proper meaning of their own, but tend to explain the relation of nouns and verbs. Such are prepositions in our language—upon, in, through, &c. It should be observed what position such words hold with relation to nouns. It is a character of one great class of languages—viz. the Tartar dialect, or the languages of High Asia—to place all such particles at the end of nouns: thus prepositions become postpositions. In most African languages, as yet known, particles are placed at the beginnings of words; and that is the case not only with prepositions, but with particles of all kinds, such as syllables which change the singular into the plural number, as Anakosah becomes the plural of Kosah. Again, in the American language, particles are as it were swallowed up by the principal words, or are inserted in the middle of them.

It may be right to observe also whether languages admit the composition of words making compound epithets by amalgamating two or more simple words.

Observe also whether the words, such as names of objects, are monosyllables, or consist of several syllables.*

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* On the subject of this article may be consulted the '*Manual of Ethnological Inquiry*, prepared by a Sub-committee of the British Association for the Advancement of Science in 1851,' which may be procured from Messrs. Taylor and Francis, Red Lion Court, Fleet Street.

ARTICLE XI.

FOURTH DIVISION, SECTION 1.

GEOLOGY.

BY CHARLES DARWIN, ESQ., F.R.S., F.G.S.

A PERSON embarked on a naval expedition, who wishes to attend to Geology, is placed in a position in some respects highly advantageous, and in others as much to the contrary. He can hardly expect, during his comparatively short visits at one place, to map out the area and sequence of widely extended formations; and the most important deductions in geology must ever depend on this having been carefully executed; he must generally confine himself to isolated sections and small areas, in which, however, without doubt, many interesting facts may be collected. On the other hand, he is admirably situated for studying the still active causes of those changes, which, accumulated during long-continued ages, it is the object of geology to record and explain. He is borne on the ocean, from which most sedimentary formations have been deposited. During the soundings which are so frequently carried on, he is excellently placed for studying the nature of the bottom, and the distribution of the living organisms and dead remains strewed over it. Again, on sea-shores, he can watch the breakers slowly eating into the coast-cliffs, and he can examine their action under various circumstances: he here sees that going on in an infinitesimally small scale which has planed down whole continents, levelled mountain-ranges, hollowed out great valleys, and exposed over wide areas rocks which must have been formed or modified whilst heated under an enormous pressure. Again, as almost every active volcano is situated close to, or within a few leagues of, the sea, he is admirably situated for investigating volcanic phenomena, which, in their striking aspect and simplicity, are well adapted to encourage him in his studies.

In the present state of the science it may be doubted whether the mere collection of fragments of rock, without some detailed observations on the district whence they are brought, is worthy of the time consumed and the carriage of the specimens. The simple statement that one part of a coast consists of granite, and another of sandstone or clay-slate, can hardly be considered of any service to geology; and the labour thus thrown away might have been more profitably spent, and thus saved the collector much ultimate disappointment. It is now generally recognised that both the sedimentary rocks, and those which have come from below in a softened state, are nearly the same over the whole world. A mere fragment, with no other information than the name of the place where found, tells little more than this fact. These remarks do not at all apply to the collection of fossil remains, on which subject some remarks will presently be made; nor do they apply to an observer collecting suites of rock-specimens, with the intention of himself subsequently drawing up an account of the structure and succession of the strata in the countries visited. For this end, he can hardly collect too copiously; for errors in the naming of the rocks may thus be corrected, and the careful comparison of such specimens will often reveal to him curious relations which at the time he did not suspect.

In order to make observations of value, some reading and much careful thought are necessary; but perhaps no science requires so little preparatory study as geology, and none so readily yields, especially in foreign countries, new and striking points of interest. Some of the highest problems in geology wait on the observer in distant regions for explanation—such as, whether the successive formations, as judged of by the character of their fossil remains, correspond in distant parts of the world to those of Europe and North America, or whether some of them may not correspond to blank epochs of the north, when sedimentary beds either were not there accumulated, or have been subsequently destroyed; and again, whether the lowest formation everywhere is the same with that in which living beings are first present in the countries best known to geologists. These and many other such wide views in the history of the world are open to any one who, applying thought and labour to his subject, has the good fortune to geologise in countries little frequented.

A person wishing to commence geology is often deterred by not knowing the names of the rocks; but this is a knowledge, he may rely on it, easily acquired. With half a dozen named crystalline rocks, or even by patiently familiarizing his eye (aided by a lens) to the aspect of the feldspar and quartz in granite, he will know the two most essential ingredients in most igneous rocks; and in granite he will often find the glittering scales of mica replaced by a dark green mineral, less hard than the feldspar and quartz; and then he will know the third most important mineral, hornblende. The sedimentary rocks can hardly be described, except by the terms in common use: impure limestone, which cannot be readily recognised by the eye, can be distinguished by its effervescence with acids. By the repeated comparison of freshly fractured sedimentary and igneous rocks, such as sandstone and clay-slate on the one hand, and granite and lava on the other, he will learn the difference between crystalline and mechanical structure; and this is a very necessary point. Let no one be deterred from geology by the want of mineralogical knowledge; many excellent geologists have known but little; and from this reason its value has perhaps sometimes been underrated, for many of the obscurer points in geology, such as the nature of the metamorphic changes in rocks, and all the phenomena of metallic and other veins, always require such knowledge. The appearances presented by the different forms of stratification (that is, the original planes of deposition) may be soon learnt in the field; though no doubt the beginner would be aided by the diagrams given in many elementary works.

Books.—The two most useful works which the geologist can carry with him are without doubt the 'Principles' and the 'Manual of Geology,' by Sir Charles Lyell. He should procure a treatise on mineralogy—for instance, 'Phillips's Mineralogy,' by Allan. If he has the opportunity to procure others, Sir H. Delabeche's 'Researches in Theoretical Geology' would be particularly desirable from its discussing many of the questions which ought especially to engage the attention of a sea voyager. As he will probably visit many volcanic regions, Dr. Daubeny's 'Treatise on Volcanos' would be extremely useful; and a list is there given of special treatises on the volcanic countries likely to be visited by him. The 'Description Physique des Isles Canaries,' by Von Buch, may be cited as a model of descriptive powers. The voyager in the Temperate and Polar regions ought to have Agassiz' work on Glaciers.

Tools and Instruments.—The geologist fortunately requires but little apparatus: a heavy hammer, with its two ends wedge-formed and truncated; a light hammer for trimming specimens; some chisels and a pickaxe for fossils; a pocket-lens with three glasses (to be incessantly used); a compass and a clinometer, compose his essential tools. One of the simplest clinometers is that constructed by the Rev. Prof. Henslow: it consists of a compass and spirit-level, fitted in a small square box; in the lid there is a brass plate, graduated in a quadrant of 90 degrees, with a little plumb-line to be suspended from a milled head at the apex of the quadrant. The line of intersection of the edge of the clinometer, when held horizontally with the plane of the stratum, gives its strike, range, or direction; and its dip or inclination, taken at right angles to the strike, can be measured by the plumb-line. In an uneven country it is not easy without the clinometer to judge which is the line of greatest inclination of a stratum; and it is always more satisfactory to be certain of the angle than to estimate it. A flat piece of rock representing the general slope can usually be found, and by placing a note-book on it the measurement can be made very accurately. In studying the cleavage or slaty structure of rocks, accurate observations are indispensable. A mouth blow-pipe with its apparatus, and a book with instructions for its use (Phillips's Mineralogy contains brief directions), teaches a little mineralogy in a pleasant manner. Besides the above instruments, a mountain barometer is often very necessary: a portable level would, in the case of raised sea-beaches and terraces, be useful. Messrs. Adie and Son, of Edinburgh, sell a hand-level, a foot in length, which is fitted with a little mirror on a hinge, so that the observer, whilst looking along the level, can see when the bubble of air is central, and thus instantly find his level in the surrounding district. This is a very valuable instrument. Mr. R. Chambers, moreover, and others have found that an observer, having previously ascertained the exact height of his eye when standing upright, can measure the altitude of any point with some degree of accuracy; he has only to mark by the level a recognisable stone or plant, and then to walk to it, repeat the process, and keep an account how many times the levelling has been repeated in ascending to the point the height of which he wishes to ascertain.

Rules for Collecting.—A few cautions may be here inserted on the method of collecting. Every single specimen ought to be numbered with a printed number (*those which can be read upside down having a stop after them*), and a book kept exclusively for their entry. As the value of many specimens entirely depends on the stratum or locality whence they were procured being known, it is highly necessary that every specimen should be ticketed on the same day when collected. If this be not done, in after years the collector will never feel an absolute certainty that his tickets and references are correct. The ticketing of every separate fossil from the same stratum is very troublesome, yet it is particularly desirable that this should be done; for when the species are subsequently compared by naturalists, mistakes are extremely liable to occur; and it should always be borne in mind that misplaced fossils are far worse than none at all. Pill-boxes are very useful for packing fossils. Masses of clay or any soft rock may be brought home if small fossil shells are abundant in them. Rock-specimens should be about two or three inches square, and half an inch thick; they should be folded up in paper. To save subsequent trouble, it will be found convenient to pack up and mark outside sets of specimens from different localities. These details may appear trifling; but few are aware of the labour of opening and arranging a large collection, and such have seldom been brought home without some errors and confusion having crept in.

Methods for Observing.—To a person not familiar with geological inquiry, on first landing on a new coast, probably the simplest way of setting to work is for him to imagine a great trench cut across the country in a straight line, and that he has to describe the position (that is, the angle of the dip and direction) and nature of the different strata or masses of rock on either side. As, however, he has not this trench or section, he must observe the dip and nature of the rocks on the surface, and take advantage of every river-bank or cliff where the land is broken, and of every quarry or well, always carrying the beds and masses in his mind's eye to his imaginary section. In every case this section ought to be laid down on paper, on as nearly as possible the real proportional scale, copious notes should be made, and a large suite of specimens collected for *the observer's own* future examination. The value of sections, with their horizontal and vertical scales true to nature, cannot be exaggerated, and their importance has only lately been appreciated to the full extent. The habit of making even in the rudest manner sectional diagrams is of great importance, and ought never to be omitted: it often shows the observer palpably, and before it is too late (a grief to which every sea-voyager is particularly liable), where his knowledge is defective.

Partly for the same reason, and partly from never knowing, when first examining a district, what points will turn out the most important, he ought to acquire the habit of writing very copious notes, not all for publication, but as a guide for himself. He ought to remember Bacon's aphorism, that "Reading maketh a full man, conference a ready man, and *writing an exact man;*" and no follower of science has greater need of taking precautions to attain accuracy; for the imagination is apt to run riot when dealing with masses of vast dimensions, and with time almost infinite. After the observer has made a few traverses of the country, and drawn his sections (and the coast cliffs often afford him an invaluable one), he will be himself astonished to find how, in the most troubled country, over which the surface has been broken up and re-cemented almost like the fragments of ice on a great river, all the parts fall into intelligible order. He will in his mind see the beds first horizontally stretched out one over the other in a fixed order, and he will then perceive that all the disturbance has arisen from a few nearly straight cracks, on the edges of which the beds have been upturned, and between which he will sometimes find great wedges of once heat-softened, but now crystalline rocks. He will find that large masses of strata have been removed and denuded, that is ground down into pebbles and mud, and long ago drifted away to form in some other area newer strata. He will now have a good idea of the physical structure of his district; and this much can be acquired with much greater facility than he will at first readily anticipate.

In examining a district to make a section, many minor points of detail will occur for observation, which can hardly be specified; such as the nature and cause of the transitions and alterations of the different strata, the source of the sediment and pebbles, the alterations in chemical nature, either of the whole mass, or of parts, as in concretions; the presence, and grouping and state of the fossil remains; the depth and condition of the old sea-bottom when the beds were deposited, and an infinity of similar points. Probably the best method of obtaining this power of observation is to acquire the habit of always seeking an explanation of every geological point met with; for one mental query leads on to another, and this will at the same time give interest to the observer's researches, and will lead him to compare what is before his eyes with all that he has read of or seen. With his increasing knowledge he will daily find his powers of observation, his very vision, become deeper and clearer. No one, however, must expect to solve the many difficulties which will be encountered, and which for a long time will remain to perplex geologists; but a ray of light will occasionally be his reward, and the reward is ample.

Organic Remains.—In the sectional diagram which we have supposed to be made, the simple superposition of the beds gives their relative antiquity; but the best section which a sea-voyager can hope to make will seldom include more than a small portion of the long sequence of known geological formations. And as the voyager seldom passes over large districts, he will rarely succeed in placing in proper order, by the aid of superposition alone, the formations which he successively meets with even in the same country. Hence he must, more than any other geologist, rely on the characters of the embedded organic remains, and must sedulously collect every specimen and fragment of a specimen. By the means of fossil remains, not only will he be enabled to arrange (with the help of naturalists on his return home) the formations in the same country according to their age, but their contemporaneity with the deposits of the most distant parts of the world can thus, and by no other method, be ascertained; for it is now known that at each geological epoch the marine animals partook in the most distant quarters of a general similarity, even when none of the species were identically the same: thus beds have been recognised in North and South America, and in India, which must have been deposited when the chalk in Europe was accumulating beneath the sea.

It is highly necessary most carefully to keep separate the fossils found in different strata; it will often occur in passing upwards from one bed to another, and occasionally even without any great change in the character of the rock, that the fossils will be wholly different; and if such distinct sets of fossils are mingled together, as if found together, undoubtedly it would have been better for the progress of science that they had never been collected. As there is some inconvenience in keeping separate the fossils collected on the same day, this caution is the more requisite. The collector, if he be not an experienced naturalist, should be very cautious in rejecting specimens, from thinking them the same with what he has already got; for it requires years of practice to perceive at once the small, but constant, distinctions which often separate species; the same species, moreover, if collected in different localities, or in beds one placed far above the other, are generally more valuable to the geologist than new species.

In formations from a few hundred to a thousand feet and upwards in thickness, the whole of which does actually belong to the same geological age, and is therefore characterized by the same fossils, most curious and important results may be sometimes deduced, if the positions or relative heights at which the groups of fossils are embedded be noted; and this is a point usually neglected. For, thanks to the researches of Professor E. Forbes, the depth of water under which a collection of shells lived can now be approximately told; and thus the movement of the crust of the earth, whilst the strata including the shells were accumulating, can be inferred. For instance, if at the bottom of a cliff, say 800 feet in height, a set of shells are buried, which must have lived under water only 50 or 100 feet in depth, it is clear that the bottom of the sea must have sunk to have allowed of the deposition of the 700 feet of superincumbent submarine strata; subsequently the whole 800 feet must have been upraised. For this same purpose, and for other ends, it is desirable that it should be noted which species are the most numerous, and whether layers are composed exclusively of single kinds. It should be also remarked, whether the more delicate bivalve shells retain their two valves united, and whether the burrowing kinds are embedded in their natural positions, as these facts show that the shells have not been drifted from afar. Where there are fossil corals, it should be observed whether the greater number of specimens are upright, in the positions in which they grew. The remark formerly made that the collection of mere fragments of rock is of little or no use to geology is far from applicable to fossil remains. Every single fossil species, bones, shells, crustacea, corals, impressions of leaves, petrified wood, &c., should be collected, and it is scarcely possible to collect too many specimens. Even a single species without any information of any kind, if it prove a quite new form, will be valuable to the zoologist; if it prove identical with, or closely allied to a known species, it may interest the geologist. A set of fossils, however, and still more several sets, with their superposition known, cannot fail to be of the highest value; they will tell the age of the deposit, and perhaps give the key to the whole geology of the country: some of the most interesting problems in this science will be solved only when large collections have been carefully made in distant regions of the world.

A collection of recent shells (both those living on the coast and those to be procured by the dredge off it) from the same country or island at which a collection of tertiary fossil shells is made, is generally of very great service to the palæontologist who undertakes the description of the fossils. The collecting of recent shells will, moreover, with the aid of a little study, teach the geologist some conchology, and this is an acquirement yearly becoming more necessary: the geologist should exert himself to learn some general zoology.

The bones of vertebrated animals are much more rarely found than the remains of the lower marine animals, and they are almost in proportion more valuable. A person not acquainted with the science will hardly be able to imagine the deep interest which the discovery of a skeleton, if of higher organization than a fish, in any of the oldest formations would most justly create. The age of such a formation would have to be judged of by the co-embedded shells, and therefore, if possible, part of the slab containing the bones should include one or two shells to demonstrate their contemporaneity. Bones, however, from any formation are sure to be valuable; even a single tooth, in the hands of a Cuvier or Owen, will unfold a whole history: the heads, jaws, and articular surfaces are the most valuable; but every fragment should be brought home. Where bones are found close together, and especially if some of the parts lie in their natural positions, they should be packed together. Every bone, if found even six inches beneath the black vegetable mould, should be collected; there can be no doubt that many most valuable relics have been neglected, from the supposition that they belonged to still living animals. Low cliffs of mud, gravel, and clay on the banks of streams and on sea-shores (as well as in bared reefs extending from them), are the most likely places for the discovery of the remains of quadrupeds. Gravel-beds under streams of lava; fissures in volcanic rocks; peat-beds, and the clay or marl underlying peat, are all favourable places. Fishes' bones are found occasionally in all sedimentary strata, and are highly interesting.

Caverns.—These most frequently occur in limestone rocks, and they have yielded a truly wonderful harvest of remains in Europe, South America, and Australia. The bones generally occur in mud, under a stalagmitic crust produced by the dripping of the lime-charged water, which requires being broken up by a pickaxe. As caverns have often been used by wild races of man as places of habitation and burial, a most careful examination should be made to detect any signs of the surface having been anciently broken up near where the bones are found. Even small islands, not now inhabited by any land quadruped, if not very distant from a continent, are almost as likely to contain osseous remains as larger tracts of land. The interest of the discovery of the remains of land quadrupeds in an oceanic island would be extreme: for instance, it has been stated that the tooth of a mastodon has been found in one of the Azores; if this were confirmed, few geologists would doubt that these islands had once been united to Europe, thus enlarging wonderfully our ideas of the ancient geography of the Atlantic: so also the remains of a mastodon are said to have been brought from Timor, thus perhaps indicating the road by which this great quadruped formerly reached Australia.

Fossil Footsteps.—As allied to organic remains, fossil footsteps may be here referred to. They have been observed in Europe and North America, but hitherto in no other part of the world. These curious vestiges not only proclaim the former existence of reptiles and birds at very remote periods, and in rocks often not containing a fragment of bone, but they generally prove that the level of the land subsided after the animal had left its impress on the ancient sea-beach, thus allowing thousands of feet of strata to be thrown down over them. The best place for searching for footsteps is in quarries of sandstone, in which the strata are separated by seams of shale. The best indication of their probable occurrence is the rock being "rippled," that is marked with narrow little wavy ridges, such as occur on most sandy shores when the tide is down, and which indicate that the now rocky surface was once either a tidal beach or a shallow surface, over which the ancient animals walked. In the case of fossil footsteps being found, the largest slab which could possibly be removed ought to be brought away, and accurate drawings, or, still better, casts, made of several of the footsteps. A plan from accurate measurement ought to be taken of any row of steps. The value of such fossil footsteps would be in a manifold degree increased, if the age of the deposit could be determined by shells found in the same stratum, or above it.

Coal Deposits.—The origin of coal presents a most curious and difficult problem in geology; and though a vast amount of information has been accumulated on the subject, yet good observations in distant countries would be of the highest value. A very brief statement of the most prominent difficulties in the theory of its origin will, perhaps, be the best guide for further inquiries. If we look first to the coal itself, the frequency with which, both in Europe and North America, upright vegetables have been found in and on the coal, and the curious relation between the presence of coal and the nature of the clayey bed (abounding with roots) on which it rests, can leave no doubt that, in these so frequent instances, the vegetation whence the coal has been derived grew on the spot where now it is embedded. The regularity and wide extent of the beds of coal, and especially of certain subordinate seams in them, the stratification and fineness of the deposits alternating with the coal, and the rarity of channels (such as would have been formed by a stream or river) cutting through the associated strata, all seem pretty clearly to indicate that the coal was not formed on the surface, like a mass of peat, but under water. What, then, was the nature of those vast expanses of shallow water under which the coal was accumulated? The character of the upright fossil plants, according to our present knowledge, absolutely contradicts the idea of their having lived in the sea; yet occasionally strata, containing undoubted marine remains, are associated with the carboniferous series. On the other hand, how can we believe that lakes, allowing of course their beds slowly to sink, could contain the enormous thickness, amounting in some instances to several thousand yards, of the coal-bearing strata? Or are we to suppose that, whilst a broad belt of low land with extensive lagoons, near the mouth of some great river, very gradually subsided, mud and sand were deposited at such a rate on the surface as to keep up the level, so that the waters of the sea were prevented, excepting in rare instances, from breaking into the lagoons with their luxuriant vegetation? On this view, or indeed on any such view, whence, it may be asked, after long-continued subsidence, sufficient to bury even a lofty mountain-chain, was derived the sediment which formed the great pile of strata alternating with the coal? Must not an adjoining area have gone on rising, whilst the coal-bearing strata continued to sink? From these few remarks it will be seen how many points deserve careful examination in any new coal district; the chief points being, *the presence of upright vegetables and trunks of trees* (of the position of which careful drawings should be made), and whether furnished with roots; *the nature of the beds on which the coal rests, and generally of all the strata; the continuousness and form of the strata, and whether ripple-marked; the existence of marine animal remains, and whether such lived on the spot, or were drifted into their present positions;* and many other similar points. It is superfluous to observe that all fossil plants should be collected; those found upright should be carefully distinguished from those embedded horizontally. The contents of any upright stems and of the roots should be examined; as it appears they have generally first become hollow from decay, and then been filled up with mud, which in some instances is charged with seeds and leaves.

Salt Deposits.—Information is much required on this subject; and this is a case in which good suites of specimens, illustrating the nature of the rocks beneath and above the salt, would possess much interest. Do they contain any organic remains? Did such live on the spot where now buried? Do the rocks show signs of having undergone in any degree the action of heat? Are the strata regular, or are they crossed by oblique layers, showing the probable action of currents? Are there ripple-marks, or beds of coarse pebbles, or other indications of the strata having been deposited in shallow water? What is the thickness, form, and dimensions of the beds of salt? Specimens of the salt, and of any associated saline substances, ought to be brought home in bottles for analysis. The origin of beds of salt, found in formations of very different ages in different parts of the world, is at present quite obscure; some authors attribute it to the sinking of superficial sea-water, rendered more saline by evaporation; others to the evaporation of sea-water periodically overflowing extensive low sandy tracts, like parts of the Run of Cutch; others suspect that its deposition is in some unknown way connected with the sea's bottom having been heated by volcanic action. In some countries there are large lakes of brine, often covering thick beds of salt; these deserve examination: on what does such salt or brine rest, whether on the bared underlying strata, or on sand or gravel, such as cover the surrounding country? Does the salt contain the remains of animals or plants? Specimens of the salt ought to be brought home in bottles, and it should be observed whether there is beneath it any thin layer of other saline substances.

Cleavage.—The slaty structure of rocks will at first perplex the young geologist; for in proportion as it becomes well developed, the planes of stratification or of original deposition become obscure, and are often quite obliterated. As the sea-voyager, and especially the surveyor, often visits numerous points on the same line of coast, he possesses some great advantages for studying this subject, and numerous observations made with care would probably give striking results. The range or strike of the cleavage is uniform over surprisingly large areas; whereas both the angle and point of dip vary much; but there is reason to believe that the planes of inclination, examined across a wide tract transversely to the range, will fall into order and show that they are the truncated edges of a few great curves or domes. *The relation of the cleavage-planes to those of the stratification, or axes of elevation, should be carefully noted, and likewise to the general outline of the whole country. Long sections at right angles to the strike of the cleavage, with the dip carefully protracted on paper*, would be highly interesting. When two chains of hills, each having its independent cleavage, cross each other, careful observations should be made. In all cases, any mineralogical difference, however slight, in the parallel cleavage-layers, deserves attention; but observations on this head would be hardly trustworthy, unless the planes of stratification were so distinct that there could be no possibility of confounding (as has often happened) cleavage and stratification. Where a stratum of sandstone, or of any other rock without cleavage, is interstratified with a slaty rock, the surface of junction ought to be minutely examined, to see if the slate has slipped along the planes of cleavage, or whether again the mass has not been either stretched or compressed at right angles to these same planes. Fossil shells have been found by Mr. Sharpe in slaty rocks, which have had their shapes greatly altered, and all in the same direction; here then we have a guide to judge of the amount and direction of the mechanical displacement which the surrounding slate-rocks have undergone.* Observations on cleavage, to be useful, must be numerous and very accurately made.

The *foliation* of the metamorphic schists, that is, the origin of the layers of quartz, mica, feldspar, and other minerals, of which gneiss, micaceous, chloritic, and hornblendic schists are composed, is intimately connected with the cleavage of homogeneous slaty rocks. Nearly all the proposed observations on cleavage are applicable to foliation. *Wherever large districts of foliated and ordinary slaty rocks unite, observations would be most desirable.* These foliated rocks have all undergone metamorphic action, that is, they have been mineralogically altered and rendered crystalline by chemical attraction, aided by heat; but this latter is a most obscure subject, one on which it would appear that much further light will not be thrown without the aid of a profound knowledge of mineralogy or chemistry. It is now known that granitic rocks, which have been fluidified (as may be told by their sending great veins into, and including fragments of, the overlying rocks), are foliated in a more or less perfect degree: in these cases the relation of the planes of foliation with those of the adjoining rocks, which have been metamorphosed but not fluidified, would be eminently curious.

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* With respect to further observations on this important point, Mr. Hopkins remarks, in his paper 'On the Internal Pressure of Rock Masses' (Cambridge Phil. Transact., vol. viii.), that "the observer should direct his attention especially to those cases in which the inclination of the cleavage planes to the bedding is either small, or nearly 45°."

Nature of the Sea-bottom.—As every sedimentary stratum has once existed as the bed of the sea or of a lake, the importance of observations on this head is obvious; and no one is so favourably circumstanced for making them as a naval officer on a surveying expedition. The *limits of depth under different latitudes at which the various marine animals live or are found strewed dead*, is perhaps the most important point for further investigation which can be suggested in the science of geology: scarcely any observations with the dredge have been made within the tropics. Not only the shells, corals, sea-urchins, crabs, &c., brought up from different stated depths, should be preserved, but the proportionate numbers of each kind be carefully noted, as well as the nature of the sea-botttom. An observer could not labour too much in this line, and especially if he would subsequently himself undertake to tabulate and work out the results.*

There is another point of view under which the bed of the sea would amply repay long-continued observations. It is well known that the nature of the bottom often changes very regularly in approaching a coast; the pebbles, for instance, increasing in size in a surprisingly steady ratio with the decreasing depth. But the means by which the pebbles are thus sorted is not known: is it by the oscillation of the waves at ordinary periods, or only during gales; or is it by the action of currents? *A chart, with the nature of the bottom carefully noted on it and the currents laid down*, would by itself throw some light on this question. The nature of the pebbles being observed, perhaps a point would be found whence they radiated. Excellent observations have been made by engineers on the travelling of shingle-beaches, but scarcely anything is known of their movement under water. In what condition are the pebbles?

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* The best kind of dredge, and the manner of using it, are described under the Zoological Section.

—are they encrusted (as often happens) with delicate corallines?—after a heavy gale are the spines of such corallines found broken? In narrow channels where there are rapid currents, and in the open sea in front of straits, where the water often deepens suddenly, what is the nature of the bottom? To what depth does the sea in a storm render the water muddy? How far from the beach, and to what depth, does the recoil of the waves, or the "undertow," act, for instance, on light anchors? At what depth can the sea wear solid rock? This may sometimes be judged of by the nature of the bottom; thus, when soft mud overlies at all times, even after gales of wind, a submarine rocky surface, which from the nature of the adjoining coast-strata we may feel sure has been worn down, we may infer that the sea at its present level, and under existing circumstances, is not a destroying but a depositing and protecting agent. Is it at the line of high or low water, or between them, that the breakers most vigorously eat into coast-cliffs? Gigantic fragments of rock, much too large to be themselves rolled about, may be seen at the foot of almost every line of high cliffs; by what means in the course of time will these be removed, as must have happened with their innumerable predecessors? Are they slowly worn away or broken up? It may be well to recollect that in the tropics the powerful action of frost in splitting stones is entirely eliminated. Our observations, moreover, on the alluvial and sub-littoral deposits of these latitudes are not perplexed by the ancient effects of floating ice. The spray of salt water, above the line of breakers, corrodes by chemical decomposition calcareous rocks; does this play any important part on other rocks? Most bold coasts are fronted by sharp promontories and even isolated pinnacles; are these *exclusively* due to the greater hardness of the rocks composing them, or do not the breakers act more efficiently when eddying round any slight projection?

Rocks rising steeply out of the open ocean, and exposed to the incessant wash of the heaviest surf, are often thickly coated over with various marine animals, and this would seem to indicate that pure water has not the power of gradually wearing away hard rocks, though the waves may occasionally tear off large fragments. Is the washing to and fro of pebbles, or of sand, a necessary element in the corroding power of waves on hard rocks? but how comes it that small land-locked harbours, where the waves can hardly have force to move the shingle, should ever be surrounded by cliffs, which, in most cases, clearly prove that considerable masses of rock have been worn down into mud and removed? Again, at a moderate depth, where the bottom is covered with shingle, does the rolling to and fro of the pebbles wear away solid rock? if, so, the pebbles would be clean, and the submarine rocky surface probably worn into furrows or channels at right angles to the beach. Where there are violent currents and eddies, are deep round holes worn in the bottom, like those produced by eddies at the foot of cascades? This, perhaps, might be ascertained by a long pole at the turn of the tide: deep round holes have been observed on rocks formerly covered by the sea, and their origin has perplexed geologists. Any person steadily attending to these subjects will occasionally be enabled to form an opinion on points at first appearing hopelessly obscure to him. The common deep-sea lead, especially if made a little bell-shaped and well armed, gives a surprisingly good picture of the bottom. There can be no doubt that whoever will for a long period collect and compare observations, made over wide areas and under different circumstances, will arrive at many curious, novel, and important results.

An observer occasionally may arrive at a district where lately some great aqueous catastrophe has occurred, such as the bursting of a lake temporarily formed by a slip, or the rush of a great earthquake-wave over low land. In such cases all the effects produced, *such as the thickness and nature of any deposit left—whether stratified irregularly or continuously—whether any rocky surface, over which the debacle has passed, be scored or smooth*; all such points should be minutely described, and measurements taken of any great blocks which may have been transported: the great desideratum is accuracy and minuteness.

Ice Action.—The voyager in the Polar Seas would render an excellent service to geology *by observing all the effects which icebergs produce in rounding, polishing, scoring, and shattering solid rocks, and likewise in transporting gravel and boulders.* Floating ice under two forms is known to transport fragments; namely, coast-ice, in which the stranded boulders are frozen, and icebergs formed by glaciers entering the sea, on the surface of which masses of rock had previously fallen from the surrounding precipices. It is obvious that in the latter case the fragments would generally be quite angular, and they could not be landed in water shallower than the thickness of the submerged ice, requisite to float the berg. On the other hand, the boulders frozen in coast-ice would generally be previously water-worn, and they could be landed on an ordinary beach, and might be driven by the force of the pack high and dry, and perhaps left piled in strange positions. *All facts illustrating the difference in the results produced by coast-ice and true icebergs would be very valuable.* Do the boulders fixed on coast-ice, when driven over rocky shoals, become themselves scored? Wherever there is reason to believe that a surface has been scored by recent ice-action, a minute description and drawings ought to be made of the depth, length, width, and direction of the grooves; and even large slabs brought home. On true icebergs, are the fragments of rock generally fixed or loose; when icebergs turn over, are fragments frequently seen embedded in that part which was under water; and how were they fixed there? The nature, number, size, form, and frequency of occurrence of all fragments of rock seen on floating ice ought to be recorded, and the distance from their probable source. A polar shore, known from upraised organic remains to have been lately elevated, would be eminently instructive. Do great icebergs force up the mud and gravel at the bottom of the sea in ridges like the moraines of glaciers? Can shells or marine animals exist in a shallow sea, often ploughed up and rendered turbid by the stranding of icebergs? The dredge alone could answer this. The means of distinguishing the effects of ancient floating ice from those produced by ancient glaciers are, at present, a great desideratum in geology. M. Agassiz' work on Glaciers, with its admirable plates, ought to be procured by any one going to the colder regions of the north or south.

Erratic boulders occur in Europe, North America, and in the southern parts of South America, which, it is believed by most geologists, were transported by ice; those near mountains, by ancient glaciers; and those on the lowlands, by floating ice. Erratic boulders, when not of gigantic size, may be confounded with rounded stones, transported by occasional great floods or by the coast-action of the surf during slow changes of level of the land. Masses of granite, from often disintegrating into large, apparently water-worn boulders, and then rolling downwards, have several times been erroneously described as belonging to the erratic class. Where the nature of all the rocks in the vicinity is not perfectly known, great size and the angularity of the fragments (though by no means a constant concomitant) are the most obvious distinctive characters; but even when the surrounding country is not at all known, the composition of a single isolated hill or small island may easily be ascertained, and if large fragments of foreign rock lie strewed on its surface, these may be assumed almost certainly to be erratic boulders. Here, however, a caution has been found necessary; for in the case of fragments of *sedimentary* rocks, they may be the last remnant of a denuded overlying formation. Wherever erratic boulders are found, their composition, form—especially observing whether they are angular, water-worn, or scored,—and their size, from actual, though rude measurements, should be given.

Both in the north and south a peculiar formation called "till" has been found connected with erratic boulders; it consists generally of mud, containing angular and rounded stones of all sizes up to the largest boulders, mingled in utter confusion, and generally without any stratification. Such deposits should be examined. Sometimes the upper beds, when they are stratified, have been found violently contorted, whilst the lower ones are undisturbed, showing that the violence has not proceeded from below, as in ordinary geological cases. Sir C. Lyell has suggested that this effect has been produced by the stranding of great icebergs.

As far as our present knowledge goes, the above enumerated phenomena—such as scored, mamillated, and polished rocks, moraines, erratic boulders, and beds of "till," though occurring in latitudes where glaciers do not now occur, where the sea is never frozen, and where icebergs are never drifted—yet have not been observed in either hemisphere higher than about latitude 40°. Hence, on whatever coast ancient ice-action may be discovered, *the limit of latitude towards the tropics at which it ceases ought to be carefully investigated.* Observations are much wanted on the west coast of North America and the east coast of Asia; and again in New Zealand and other islands of the Southern Ocean. The period of the ice-action is pretty well ascertained in Europe and North America, and a very great service would be rendered to geology if the same point could be clearly made out in the southern hemisphere; for it might greatly influence our ideas on the climate of the world during the late tertiary periods. Any shells embedded in "till" (unfortunately of very rare occurrence) would decide this point, and it might probably be closely judged of, if "till" or boulders were found resting on, or covered by, shell deposits.

Distribution of Organic Beings.—As geology includes the history of the organic inhabitants, as well as of the inorganic materials, of the world, facts on distribution come under its scope. Earth has been observed on icebergs in the open ocean; *portions of such earth ought to be collected, washed with fresh water, filtered, gently dried, wrapped up in brown paper, and sent home by the first opportunity, to be tried, with due precautions, whether any seeds still alive are included in it.* Again, the roots of any tree cast up on an island in the open ocean should be split open, to see if any earth or stones are included (as often happens), and this earth ought to be treated like that from icebergs: it is truly surprising how many seeds are often contained in extremely small portions of earth. Any graminivorous bird, caught far out at sea, ought to have the contents of its intestines dried for the same object. The zoologist who, with a towing-net, fishes for floating minute animals, ought to observe whether seeds are thus taken. These experiments, though troublesome, undoubtedly, would be well worth trying. All facts or traditional statements by the inhabitants of any island or coral-reef, on the first arrival of any bird, reptile, insect, or remarkable plant, ought to be collected. In those rare cases in which *showers of fish, reptiles, shells, earth, seeds, confervæ, &c., have fallen from the sky, every fact should be recorded, and specimens collected.*

Volcanic Phenomena.—The voyager will probably have ample opportunities of examining volcanic islands, and perhaps volcanoes in eruption. With respect to the latter, he ought to record all that he sees: should the exact position of the orifice be known, he might, perhaps, by observing some point in a cloud, measure with a sextant to what height the fragments were shot forth, and the height of the often flat-topped column of ashes. Having surveying instruments, he ought to map, as carefully as time will permit, any crater remarkable for its size, depth, or peculiar form. M. Élie de Beaumont has found that, owing to the fluidity of lava, streams never consolidate into a thick, moderately-compact mass, except on a surprisingly gentle inclination. On a slope of above 2° or 3° the stream consists of extremely irregular masses, often forming a hollow vault within. Fresh observations on this point are much wanted in regard to lavas of different composition. The measurements can easily be made by a sextant and artificial horizon.* In making such observations,

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* M. Élie de Beaumont gives the following directions (Mémoires pour servir, &c., tom. iv. p. 173):—

"The method I am in the habit of employing for these kinds of comparatively recent streams must be chosen, so that there can be no doubt that the whole consists of a single stream: this cannot be judged of without examining the whole line between the two points of measurement, for some liquid lavas thin out to a very fine edge; and two streams, one over the other, may be thus very easily mistaken for a single one. The composition, thickness, and degree of cellularity of any lava-stream, of which the slope is measured, ought to be described as seen on the sides of fissures, and wherever its internal structure can be made out.

Round many active and extinct volcanoes, both on continents and on islands, there is a circle of mountains, steep on their inner, and gently inclined on their outer flanks. The volcanic strata, of which they are composed, everywhere dip away from the central space, but at a considerably higher angle than it is believed lava can consolidate into such thick and compact masses. These mountains form the so-called "craters of elevation," the origin of which has excited much controversy, and which demand further

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measurements is simple and easy, and a description of it may save useless trouble to others. I place on the edge of the sextant, and behind the fixed mirror, a small piece of white paper, in which there is a narrow opening (ouverture étroite) corresponding to the axis of the telescope. On the exterior surface of the paper a black line is drawn, perpendicular to the plane of the graduated circle, and passing through the centre of the opening above mentioned. A quantity of mercury is poured into a vessel sufficient to form a plane horizontal surface of a certain extent. The telescope of the sextant is then directed vertically over the mercury, and the image of the black line sought for. When this is found, I am certain that the visual ray from the image in the mercury can only deviate from the perpendicular, in so far as the line is not without breadth, and the opening has a sensible size. These two sources of error can be diminished so that the maximum of error shall not exceed a minute. Being once certain of the verticality of the visual ray from the image of the black line, I have only to make the image of any object reflected from the moveable mirror coincide with that of the black line, to have the angle between the vertical and the line drawn from the centre of the instrument to the object in question, which may be any distant point on the surface of a bed of lava, a glacier, a road, a river, &c."

examination. There is a grand range of mountains of this class at the Mauritius and at St. Jago in the Cape de Verdes, parts only of which have been described. The chief points to attend to are, the *inclination* of the streams by actual measurement, their thickness, compactness, and composition; the *form and height of the mountains*, and whether they have suffered much wear and tear from the ancient action of the sea when the land stood at a lower level, for Sir C. Lyell has lately attributed their origin almost exclusively to this agency; and *whether they are traversed by very many dikes*, of which the common direction ought to be recorded; *how far the mountains stand apart, and the diameter and outline of the rude circle which they together form.* In fact, a most useful service would be rendered by mapping any of these "craters of elevation," or, what would be more feasible, drawing from actual measurements two sections at right angles to each other, across the circle.

Some streams of lava, especially those belonging to the trachytic series (harsh, generally rather pale-coloured lavas, with crystals of glassy feldspar), are laminated. The *course of the layers with respect to the course of the stream* ought to be minutely studied, both on the surface, at the termination, and on the flanks of the stream; and, if by a most fortunate chance there should have been formed a transverse section, throughout its entire thickness: this would be a very interesting subject for investigation. A series of specimens ought to be brought away to illustrate the nature of the lamination.

Aërial Dust.—Fine brown-coloured dust has often fallen on vessels far out at sea, more especially in the middle of the Atlantic. This should be collected; the direction and force of the wind (and the course of any upper current, as shown by the movement of the clouds) on the same day, and for some previous days, ought to be recorded, as well as the date, and the position of the ship. Such dust has been shown by Ehrenberg to consist, in many cases, almost entirely of the siliceous envelopes of infusoria. The distance to which real volcanic dust is blown is, likewise, in some respects well worth determining.

Elevation of the Land.—The changes of level, often accompanying earthquakes, will be treated of by Mr. Mallet, but a few remarks on the nature of the evidence to be sought on changes of level not actually witnessed by man, may be here inserted. Many appearances, such as lines of inland cliffs, of sand-hillocks, eroded rocks, and banks of shingle, often indicate the former effects of the sea on the land when the latter stood at a lower level. But the best evidence, and the only kind by which the period can be ascertained (for the appearances above enumerated, though well preserved, may sometimes be of considerable antiquity), is the presence of upraised recent marine remains. On land which has been elevated within a geologically recent time, sea shells are often found, either embedded in thin layers of sand and mould, or scattered on the bare surface. In these cases, and especially in the latter case, great caution is requisite in testing the evidence; for man, birds, and hermit-crabs often transport, in the course of ages, an extraordinary number of shells. In the case of man, the shells generally occur in heaps, and there is reason to believe that this character is long preserved. To distinguish the shells transported by animals from those uplifted by the movement of the earth, the following characters may be used:—Whether the shells had long lain dead under water, as indicated by barnacles, serpulæ, corallines adhering to their *insides;* whether the shells, either from not being full grown or from their kind, are too small for food; remembering that certain shells, as mussels, may be unintentionally transported by man or other animals in their young state adhering to larger shells; and lastly, whether all the specimens have the same appearance of antiquity. Some shells, which have been exposed for many ages, yet retain their colours in a surprising manner. The very best evidence is afforded by barnacles and boring shells being found attached to or buried in the rock, in the same positions in which they had lived; these may be sometimes found by removing the earth or birds' dung covering points of rock. Where shells are embedded in a superficial layer of soil, though it may appear exactly like vegetable mould, specimens of it should be preserved, for the microscope will sometimes reveal minute fragments of marine animals. In all these cases, specimens of the shells, though broken and weathered, and having a wretched appearance, must be carefully preserved; for a mere statement that such upraised shells resembled those still living on the beach is absolutely of no value. It should be noticed whether the proportional numbers between the different kinds appear to be nearly the same in the upraised shells and in those now cast on the beach. The height at which the marine remains occur above the level of the sea should be measured. In confined situations, where the change of level appears to have been small, much caution must be exercised in receiving any evidence; as a change in the direction of the currents (resulting from alterations in neighbouring submarine banks) may cause the tide to flow to a somewhat less height, and thus give the appearance of the land having been upraised.

Wherever a tract of country can be proved to have been recently elevated, its surface, as exhibiting the late action of the sea, is a fertile field for observation. On such coasts, terraces rising like steps, one above another, often occur. Their outline and composition should be studied, diagrams made of them, and their height measured at many and distant parts of the coast. There is reason to believe that in some instances such terraces range for surprisingly long distances at the same height. Where several occur on opposite sides of a valley *a spirit level* is almost indispensable, in order to recognise the corresponding stages. Where ranges of cliffs exist, *the marks of the erosion of the waves* may sometimes be expected to occur; and as these generally present a defined line, it is particularly desirable that their horizontality should be ascertained by good levelling instruments, and, if they be not horizontal, that their inclination should be measured. Where more than one zone of erosion can be detected all should be levelled, for it does not necessarily follow that the several lines are parallel. Along extensive coasts, and round islands which have been uplifted to a considerable height, and where we now walk over what was, within a late geological period, the bed of the sea, it would be well to observe whether extensive sedimentary deposits have been upraised; for it has often been tacitly assumed that sedimentary deposits are in process of formation on all coasts.

Subsidence of the Land.—This movement is more difficult to detect than elevation, for it tends to hide under water the surface thus affected. Evidence, therefore, of subsidence is very valuable; and this movement, moreover, has probably played a more important part in the history of the world than elevation, for there is reason to believe that most great formations have been accumulated whilst the bed of the sea was sinking. Subsidence may sometimes be inferred from the *form of the coast-land;* for instance, where a line of cliffs, too irregular to have been formed by elevation alone, plunges precipitously into a sea so profoundly deep that it cannot be supposed that the now deeply submerged portions of the cliff have been simply worn away by the currents. The direct evidence of subsidence, if not witnessed by man, is almost confined to the presence of stumps of trees, peat-beds, and ruins of ancient buildings, partly submerged on tidal beaches. Ancient buildings may sometimes afford such evidence in unlikely situations: it has been asserted that in one of the volcanic islands in the Caroline archipelago there are ruins with the steps covered by the sea. Again, at Terceira, at the Azores, there is an old church or monastery said to be similarly circumstanced.

*Coral Reefs.**—The most important point with respect to coral reefs, which can be investigated, is, the depth at which the bottom of the sea, *outside the reef*, ceases to be covered with a continuous bed of living corals. This can be ascertained by repeated soundings with a heavy and very broad bell-shaped lead, armed with tallow, which will break off minute portions of the corals or take an exact impression of them: it can thus also instantly be seen how soon the bottom becomes covered with sand. This limit of depth ought to be ascertained in different seas, under different latitudes, and under different exposures. For collecting specimens of the corals, it is to be feared that the dredge would become entangled, but chains and hooks may be lowered for this purpose. There is reason to suspect that different species of corals grow in different zones of depth; so that in collecting specimens, the depth at which each kind is found, and at which it is most abundant, should be carefully noted. It ought always to be recorded whether the specimen came from the tranquil waters of a lagoon or protected channel, or from the exposed outside of the reef. The small reefs within the lagoons of certain atolls (or lagoon-islands) in the Indian Ocean all rise to the surface; whereas in other atolls not a single reef rises within several fathoms of the same level. It would be a curious point to ascertain whether the corals in these cases consisted of the same species; and if so, on what possible circumstance this singular difference in the amount of their upward growth has depended.

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* The only work specially written on this subject is 'The Structure and Distribution of Coral Reefs,' by Mr. Darwin.

Any facts which can elucidate the *rate at which corals can grow under favourable circumstances* will ever be interesting: nor should negative facts, showing that within a given period reefs have not increased either laterally or vertically upwards, be neglected. In a full-grown forest, to judge of its rate of growth, a part must be first cut down; so is it probably with reefs of corals. The aborigines of some of the many coral islands in the great oceans might perhaps adduce positive facts on this head; for instance, the date might be known when a channel, since closed by the growth of the coral, had been cut to float out a large canoe.

For the classification of coral reefs, the most important point to be attended to is the inclination of the bed of the adjoining sea; and, secondly, the depth of the interior lagoon in the case of atolls, and of the channel between the land and the reef, in Encircling or Barrier, and in Fringing reefs. Whenever it is practicable, soundings ought to be taken at short ascertained distances, from *close* to the breakers in a straight line out to sea, so that a sectional outline might be protracted on paper. In those cases in which the bottom descends by a set of ledges or steps, their form ought to be particularly attended to; and whether they are covered with sand or by dead or living coral; and whether the corals differ on the different ledges. The same points should be attended to within the lagoon, wherever its bed or shore is step-formed: the origin of these steps or ledges is at present obscure. In the Indian and Pacific Oceans there are entire reefs, having the outline of atolls or lagoon-islands, lying several fathoms submerged; there are likewise defined portions of reefs both in atolls and in encircling reefs similarly submerged. It would be particularly desirable to ascertain what is the nature of these submerged surfaces, whether formed of sand or rock or of living or dead corals. In some cases two or more atolls are united by a linear reef; the form of the bottom on each side of this connecting line ought to be examined. Where two atolls or reef-encircled islands stand very near each other, the depth between them might be attempted by deep soundings: the bottom has been struck between some of the Maldiva atolls. Generally the form and nature of the reefs encircling islands ought to be compared in every respect with the annular reefs forming atolls.

On the shores of every kind of reef, especially of atolls and of land encircled by barrier reefs, *evidence of the slow sinking of the land* should be particularly sought for; for instance, by stumps of trees, the foundation-posts of sheds, and wells or graves or other works of industry now standing beneath the level of high-water mark, and which there was good reason to believe must have once stood above its level. The observer must bear in mind that cocoa-nut trees and mangroves will grow in salt water. If such evidence be found, inquiry ought to be made whether earthquakes have been felt. On the other hand, all masses of coral standing so much above the level of the sea that they could not have been thrown up by the breakers during gales of wind, at a period when the reef had not grown so far out seaward, should be investigated and their height measured. There is reason to believe that some coral-reefs have been thought to have been upraised, owing to the effect of the lateral or horizontal extension of the reefs having been overlooked; for the necessary result of this outward growth is gradually to break the force of the waves, so that the rocks, now further removed from the outer breakers, become worn to a less height than formerly, and the more inland corals, not being any longer constantly washed by the surf, cease to live at a level at which they once flourished. It is indispensable that specimens of all upraised corals, and especially of the shells generally associated with them, should be collected; for there can be no doubt that ancient strata containing corals have in some instances been confounded with recent coral-rock. The importance of ascertaining whether coral-reefs have undergone, or are undergoing, any change of level, depends on the belief that all the characteristic differences between Atolls and Encircling reefs on the one hand, and Fringing reefs on the other, depend on the effect produced on the upwardly-growing corals by the slow sinking or rising of their foundations.

A thick and widely-extended mass of upraised recent coral rock has never yet been accurately examined, and a careful description of such a mass—especially if the area included a central depression, showing that it originally existed as an atoll—is a great desideratum. Of what nature is the coral-rock; is it regularly stratified or crossed by oblique layers; does it consist of consolidated fine detritus or of coarse fragments, or is it formed of upright corals embedded as they grew? Are many shells or the bones of fish and turtle included in the mass, and are the boring kinds still in their proper positions? The thickness of the entire mass and of the principal strata should be measured, and a large suite of specimens collected.

In conclusion, it may be re-urged that the young geologist must bear in mind that *to collect specimens* is the least part of his labour. If he collect *fossils*, he cannot go wrong; if he be so fortunate as to find the *bones of any of the higher animals*, he will, in all probability, make an important discovery. Let him, however, remember that he will add greatly to the value of his fossils by *labelling* every single specimen, by never *mingling* those from *two formations*, and by describing the *succession of the strata* whence they are disinterred. But let his aim be higher: by making sectional diagrams as accurately as possible of every district which he visits (nor let him suppose that accuracy is a quality to be acquired at will), by collecting for his own use, and carefully examining, numerous rock-specimens, and by acquiring the habit of patiently seeking the cause of everything which meets his eye, and by comparing it with all that he has himself seen or read of, he will, even if without any previous knowledge, in a short time infallibly become a good geologist, and as certainly will he enjoy the high satisfaction of contributing to the perfection of the history of this wonderful world.

ARTICLE XII.

FOURTH DIVISION, SECTION 2.

MINERALOGY.

BY THE LATE SIR HENRY DE LA BECHE, C.B., F.R.S., &c.

Revised by W. H. MILLER, ESQ.,
Professor of Mineralogy in the University of Cambridge.

A GLANCE at the best treatises on mineralogy, even those wherein the matter is most condensed, is sufficient to show that a profound acquaintance with this science can only be acquired by careful study, and by means of a competent knowledge of certain other sciences, the aid of which must be obtained properly to comprehend the internal and external structure and chemical composition of minerals. The naval man may nevertheless accomplish much, more especially respecting the mode of occurrence and probable origin of minerals under certain conditions, and he may also add by his researches to the catalogue of known substances of this class, and may discover new varieties of known minerals.

To classify the natural substances described under the head of mineralogy, very various methods have been adopted, chiefly, however, divisible into those based upon their external characters or chemical composition. The best classification hitherto proposed appears to be that of G. Rose, in his work entitled 'Das Krystallo-chemische Mineralsystem: Leipzig, 1852.' It is recommended by the great general resemblance of the minerals constituting each chemical group.

The fifth edition of Naumann's Mineralogy, published in 1859, contains a list of 636 minerals, supposed really to differ sufficiently to be so separated, independently of many merely considered as varieties, or accidental. It will be obvious that a voyager, especially when his general time may be occupied with other duties (only a portion of it applicable to mineralogy, and that irregularly), cannot expect to make himself familiar with all these substances. With many of those more commonly found he will have little difficulty, and by practice he will readily detect them when presented to his attention. Those which form the constituents of rocks it is especially necessary to learn and distinguish, since so much of geological importance often turns upon their proper determination. Those which are referable to the useful class should engage his attention, since while, on the one hand, valuable ores of the useful metals and other important substances are often neglected (even in our mining districts unusual though valuable ores have been thrown away at no remote times); on the other, many a mineral, commercially worthless, is treasured up, often even to the neglect of those of high value, some particular brilliancy of appearance or fancied resemblance to precious or metallic substances having misled the collector.

However desirable it may be to consider inorganic matter as a whole, the conditions under which its parts have been found to combine either naturally or artificially being only regarded with reference to the general subject, so that the natural bodies, commonly termed minerals, merely constitute a portion of this whole, it is important that the voyager be enabled to distinguish natural minerals, both as respects science and its applications. If he possessed no other means of distinguishing minerals from each other than chemistry afforded him, he would in many instances, from the want of the needful space and appliances on board ship, have the extent of his mineralogical labours greatly abridged. At the same time, with a box containing certain chemical substances, a slight apparatus, and a blowpipe, he will, after a little practice, find his power to distinguish minerals chemically far greater than he might at first anticipate.

For an account of the characters of minerals, and the methods of observing them, the voyager is referred to any of the following treatises:—Blum, 'Lehrbuch der Oryktognosie: Stuttgart, 1854.' Dana, 'System of Mineralogy: New York and London, 1854.' Dufrénoy, 'Traité de Minéralogie: Paris, 1856.' Haidinger, 'Handbuch der bestimmenden Mineralogie: Wien, 1851.' Kengott, 'Tabellarischer Leitfaden der Mineralogie: Zürich, 1859.' Naumann, 'Elemente der Mineralogie: Leipzig, 1859.' Nicol, 'Manual of Mineralogy: London, 1849.' Phillips, 'Elementary Introduction to Mineralogy: London, 1852.' Quenstedt, 'Handbuch der Mineralogie: Tübingen, 1854.

The characters of greatest importance in the discrimination of mineral species are—form, cleavage, fracture, lustre, colour, streak, hardness, specific gravity, and the chemical reactions. Hardness, lustre, colour, and streak are easily observed, yet, being frequently alike in different minerals, and not admitting of being measured with much accuracy, they cannot be considered as exact determinative characters. Specific gravity is an important distinctive character, and admits of being observed with exactness. The observation, however, which requires the use of a delicate instrument, must be made very carefully, in order to be of value. The form, cleavage, and the chemical reactions, lead with most certainty to the determination of the species of a mineral.

On breaking a crystallized mineral, it generally exhibits a tendency to split in the direction of one or more planes, called cleavages. In many cases the blow of a small hammer is sufficient to produce the cleavage: in other cases the mineral, supported upon a block of wood or metal, must be struck by the point of a punch, or the edge of a small chisel, having its edge nearly in the direction of the cleavage, driven by a hammer. The cleavage of a small bit of a mineral may be obtained by pressing it between the edges of a wire-nippers. It is found that in the same mineral the cleavages are always disposed in the same manner, forming constant angles with each other, and with the faces of the crystal.

Instruments called *goniometers* have been invented for measuring the angles which the faces (including the cleavage-planes under that term) make with each other. By comparing the observed angles with the angles recorded in books on Mineralogy, we either arrive at once at a knowledge of the species of the mineral, or else ascertain that it belongs to one of a more or less limited number of species. For this purpose the cleavages are usually more useful than the natural faces, because, being brighter, the angles they make with each other can be more easily and more accurately measured, and also because, being fewer in number, there is little difficulty in identifying them with the cleavages recorded in the descriptions of mineral species.

Carengeot's goniometer, used by Hauy, is incapable of affording results sufficiently accurate; Wollaston's reflective goniometer is consequently the only instrument the use of which can be recommended. A full description of the method of observing with it is given in Phillips's 'Mineralogy,' edition of 1852. It is a common mistake to suppose that crystals seldom occur with faces sufficiently bright for measurement with this instrument. When a small screen, at a distance of from 10 to 20 feet from the observer, having in it a hole of a square inch in area, through which the light of the sun is reflected from a plane mirror, is used for the bright signal, it is difficult to find crystals which have not faces bright enough to allow the angles they make with each other to be measured with very tolerable accuracy. The flame of a good lamp or candle serves very well for the bright signal, but is much inferior to sunlight. Descriptions of other contrivances for measuring the angles between the faces of crystals will be found in the 'Sitzungsberichte der Mathematische-Naturwissenschaftlichen Classe der k. Academie der Wissenschaften in Wien,' vols. xiv. xvii.; in 'Silliman's Journal' for September, 1857; and in the 'Philosophical Magazine' for July, 1858.

A knowledge of elementary crystallography sufficient for the observer's purpose may be gained from the chapter on that subject usually given in mineralogical treatises, or from either of the following works, with the assistance, if possible, of a small collection of models of crystals:—Kopp's 'Einleitung in die Krystallographie: Braunschweig, 1849.' Rammelsberg's 'Krystallkunde: Berlin, 1852.' Regnault's 'Crystallography.' Rose's 'Elemente der Krystallographie: Berlin, 1838.' In addition to the list of books here given, the student would do well to purchase a good set of models in wood. Such a collection, by the excellent crystallographer H. Dauber, can be procured at a moderate price through Messrs. Williams and Norgate, Henrietta-street, Covent Garden. The collection, consisting of 80 models, costs 1*l.* 13*s.* in Brunswick. The additional charges for carriage to England, duty, &c., amount to 10*s.*, making the total cost 2*l.* 3*s.* A smaller set of 50 models would cost about 1*l.* 14*s.*

Care must be taken not to confound true crystals with pseudomorphous minerals, which in form resemble certain known minerals, but have a different chemical constitution. Some of these appear to have been produced by the filling of a mould, left by the disappearance of one mineral, with the matter of another of dissimilar chemical composition. Thus at St. Agnes and St. Just, in Cornwall, cavities left by crystals of felspar are found to be filled up with a mixture of grains of stannic acid and quartz sand. Others would appear to have been formed in a different manner, there being little reason to suppose that, like the pseudomorphous minerals before mentioned, they have merely filled up moulds left by the disappearance of the original minerals. On the contrary, the elements of the new mineral seem gradually to have replaced the old mineral, so that the original form is always retained. Now and then specimens are found wherein parts of the original crystals still occur, the remainder being replaced by another substance.

Further information on the subject of pseudomorphous minerals is to be found in Haidinger's papers in Poggendorff's 'Annalen,' vol. ii. pp. 173, 366; vol. lxii. p. 161; and in Blum's 'Die Pseudomorphosen des Mineralreichs: Stuttgart, 1843.' 'Erster Nachtrag: Stuttgart, 1847.' 'Zweiter Nachtrag: Heidelberg, 1852.' An abstract of

Blum's treatise and first supplement is given by Dana in 'Silliman's Journal' for 1845, vol. xlviii. p. 66, and 1848, vol. vi. p. 267.

It is probable that to chemical composition the voyager will chiefly look for aid, more especially if he be a medical officer, and therefore likely to have become sufficiently acquainted with chemistry for the purpose. The following works will be found useful:—Will's 'Outlines of Qualitative Analysis,' Fresenius's 'Qualitative and Quantitative Analysis,' Parnell's 'Qualitative and Quantitative Analysis,' Rammelsberg's 'Leitfaden fur die qualitative chemische Analyse,' Rammelsberg's 'Anfangsgründe der quantitativen mineralogisch- und metallurgisch-analytischen Chemie,' Rammelsberg's 'Handwörterbuch des chemischen Theils der Mineralogie,' and Rose's 'Analysis,' translated by Normandy. We would suggest that no surveying voyage should be sent, more particularly to distant countries, without one of those little chests of needful things for chemical research which are prepared for the purpose.* The determination of the chemical composition of a mineral by the wet method is not likely to succeed, except in the hands of a person tolerably well versed in practical chemistry; but by a little practice much knowledge of the constituents of a mineral may be acquired by the blowpipe, or what may be termed the dry method. Works are especially dedicated to this mode of investigation. As these may not be at hand, Mr. Warington Smyth, Professor of Mining and Mineralogy in the Government School of Mines, and Museum of Practical Geology, Jermyn Street, and who has long employed the blowpipe in his researches, has prepared the following short notice of the mode in which this instrument may be rendered useful:—

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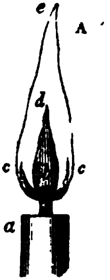
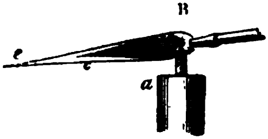
* Griffin (of Glasgow, and of Bunhill Row, London) and others fit up very compact and useful chests of this kind. They necessarily vary in price according to their contents. For about 8*l.* a chest of about 1½ cubic feet, not a cumbrous size for a cabin, may be obtained. It would contain apparatus and substances sufficient for discriminating all well-known ores and minerals, including a blowpipe apparatus with the necessary fluxes and re-agents, as also a selection of the most useful instruments for testing in the wet way, with a collection of tests in the dry state, and stoppered bottles to contain solutions; also a set of bottles with pure acids.

More complete chests may be obtained for about 15*l.* or 16*l.*—far more valuable for long voyages, during which deficiencies cannot be expected to be supplied. These are divided into two chests, one containing the things needful for more constant, the other large articles for occasional use, as well as duplicates of apparatus liable to be broken, with an extra stock of chemicals. These chests usually occupy about 4 cubic feet, and contain apparatus and chemicals sufficient for the complete quantitative analyses of minerals, or the separation of the component parts of a mineral, in quantities sufficient for an accurate analysis. They include platinum crucibles, Bohemian test tubes, Berlin porcelain crucibles and capsules, complete blowpipe apparatus, &c. &c.

The ordinary blowpipe is so well known as scarcely to need description. Various forms have been recommended by their inventors, but for common purposes it is only important that the orifice be not too large, and that the tube be provided with a reservoir for the reception of the moisture which is carried into it with the breath. The flame of a neatly trimmed lamp is undoubtedly the most convenient, but that of a common candle is quite applicable to the qualitative tests with which we shall have occasion to deal.

In looking at the flame of a candle we may observe two principal divisions, which it is necessary by the assistance of the blowpipe to use separately, since their action on the same substances is so different, as on the one hand greatly to facilitate certain processes of analysis, and on the other to cause much perplexity unless clearly understood.





The outer and larger part of the flame *e*, *d*, *c*, which is the source of its light, is caused by the full combustion of the gases derived from the oil, wax, or tallow which rises into the wick, and is called the *reducing flame*, because, when concentrated upon the substance to be tested, it tends to abstract oxygen from it and thus to reduce it. In the lower part of the flame a narrow stripe of deep blue may be observed, *b*, *c*, which when acted on by the current of air from the blowpipe forms a cone, *b*, *c* (B). This is technically called the *oxidizing flame*, from its property of imparting oxygen to the substance upon which it is directed. To produce the latter, the point or jet of the blowpipe should be inserted into about a third of the flame, and the assay is then to be held at the extremity of the cone of blue flame. For reduction the point of the tube should scarcely penetrate the flame, and the assay should be so placed as to be completely enveloped in it, and thus prevented from receiving oxygen.

A little practice is sufficient to overcome the slight difficulty which at first is felt in keeping up a continual and even stream of air. The tyro may begin by accustoming himself to breathe through the nostrils whilst his cheeks are inflated, and will soon find it easy to maintain an uninterrupted supply for several minutes.

Of the instruments used in experimenting by the blowpipe, the following are the most necessary :—1st. A pair of fine-pointed forceps, tipped with platinum. 2nd. A small spoon of platinum. 3rd. An agate pestle and mortar. 4th. Thin platinum wire and holder. 5th. A magnet. 6th. A few small tubes of thin glass. 7th. Some small porcelain capsules or saucers. Charcoal is required as a support in many cases, particularly in the reduction of ores; and the following re-agents are also indispensable, the three first being fluxes applicable under different circumstances :—

1st. Soda, or carbonate of soda.

2nd. Borax, or borate of soda.

3rd. Microcosmic salt, or phosphate of soda and ammonia.

4th. Saltpetre, to increase the degree of oxidation of certain metallic oxides.

5th. Borax-glass, for the determination of phosphoric acid, and of small quantities of lead in copper.

6th. Nitrate of cobalt in solution, or oxalate of cobalt in powder, to distinguish alumina, magnesia, and oxide of zinc.

7th. Oxide of copper, for determining small quantities of chlorine in compounds.

8th. Fluor-spar, for the recognition of lithia, boracic acid, and gypsum.

9th. Lead in a pure metallic state.

10th. Bone-ashes (9th and 10th are used for separating the silver from certain argentiferous ores).

11th, 12th, and 13th. Hydrochloric, sulphuric, and nitric acids.

14th. Litmus-paper, blue and red, for detecting the presence of acids and alkalies.

The experiments on an unknown mineral must be made systematically, and referred for comparison to some list or table of minerals in which their behaviour before the blowpipe is described, as Von Kobell's tables.*

The first point to examine is, whether it be fusible; and if so, in what degree. The various grades of fusibility may be conveniently divided into six; as representatives of which it is convenient to take the following minerals, species which are everywhere easy to obtain, and which may therefore be often practised upon:—

1. Antimony-glance, or sulphuret of antimony, which melts at the candle.
2. Natrolite or mesotype, fine splinters of which may be rounded by the candle-flame.
3. Almandine, or precious garnet, which fuses in large pieces before the blowpipe.
4. Actinolite (hornblende), fusible only in smaller portions.
5. Orthoclase (felspar) offers some difficulty; and
6. Bronzite can only be rounded by the flame in the finest splinters.

According to this scale, the mineral in question may be referred to either of the above numbers, or placed half-way between any two of them; as for instance, apophyllite, being more easily fused than natrolite, and yet more refractory than antimony-glance, will have its comparative fusibility represented by 1·5.

The fragment to be experimented upon is generally held in the platinum forceps, but it is necessary to guard against the melting of the test upon the points, since the platinum, though infusible, is by that means rendered brittle.

In other cases the mineral may be supported upon charcoal; but whatever be the means of holding it, the phenomena exhibited by the action of the flame must be noted, as

1st. The manner in which it fuses, whether quietly, or with decrepitation, exfoliation, intumescence, or phosphorescence; whether it loses or retains colour and transparency.

2nd. The appearance of the product, whether a *glass*, an *enamel*, or a *slag;* or, as in the case of ores reduced upon charcoal, a metallic bead or *regulus*.

3rd. The separation of volatile substances, and the colour of the deposit on the charcoal, by which we may recognise—

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* Von Kobell, 'Tafeln zur Bestimmung der Mineralien;' and the same translated into English by R. Campbell. A sixth and improved edition of this excellent work was published at Munich in 1858.

- *a*. Lead, giving a greenish yellow deposit.
- *b*. Zinc, having a white crust, which when heated becomes yellowish and difficult to volatilize.
- *c*. Antimony, a white deposit, easy to volatilize.
- *d*. Bismuth, a crust partly white, partly orange-yellow, without colouring the flame.
- *e*. Sulphur, with the well-known odour of sulphurous acid.
- *f*. Selenium, in an open glass tube, gives a red deposit of selenium.
- *g*. Tellurium, in a similar glass tube, gives a greyish-white crust of its oxide.
- *h*. Arsenic gives off a greyish-white vapour, which smells like garlic.
- *i*. Quicksilver, in a glass tube, will be precipitated in minute metallic globules.
- *k*. Water, from hydrous minerals, deposited by condensation in the same manner.

4th. The colour of the flame when the tip of the blue part is neatly directed upon the mineral; whence may be distinguished—

- *a*. Red tint, given by several minerals containing strontia and lithia.
- *b*. Green, produced by some phosphates and borates, sulphate of baryta, some copper ores and tellurium ores.
- *c*. Blue, given by chloride of copper, chloride of lead, &c.

5th. The development of magnetic properties after treatment in the reducing-flame, as in ores of iron, nickel, and cobalt.

So far the assay has been considered by itself, but it is frequently necessary to mix it with fluxes, either to render it fusible or to produce a glassy compound of a characteristic colour.

Thus if borax or microcosmic salt be fused into a glass at the end of a platinum wire bent into an eye, and a little powder of the unknown mineral be added to it, we shall obtain by the use of the oxidizing flame the following results:—

Manganese, in all its compounds, gives a beautiful violet or amethyst colour.

Cobalt causes a sapphire-blue colour; chromium an emerald-green.

Oxide of iron produces a yellowish-red glass, which becomes paler as it cools, and at length grows yellow or disappears.

Oxide of cerium gives a red or dark-yellow colour, which also grows paler as it cools.

Oxide of nickel renders the glass a brown or violet tint, which after cooling becomes reddish-brown.

Oxide of copper in very small quantity gives a green tint, which grows blue in cooling.

Oxide of uranium renders the glass bright-yellow, which in cooling takes a greenish tint.

Oxide of antimony gives a pale yellow colour, which soon disappears.

When soda is used as a flux, it is generally upon charcoal, and by this aid the metals may be obtained from most of their combinations in a pure state. For this purpose the powdered ore is either mixed with the moistened soda in a paste, or is enveloped in a piece of thin paper which has been dipped in a solution of soda. After fusion, that portion of the charcoal which has absorbed any of the fluid substance is to be cut off and ground down with it in the mortar, when the metal, if malleable, will at once be recognised. If several metals are combined, of which one is more easily oxidized than another, as for instance lead when combined with silver or copper, the latter may be separated by adding metallic lead or boracic acid, according to circumstances, and maintaining a continued oxidizing flame, till the whole of the lead has passed into the state of litharge.*

The voyager should be provided with hammers of different sizes, stone-cutters' chisels for breaking off crystals, and a watchmaker's forceps for picking the detached crystals out of cavities in which they cannot be reached with the fingers. Tools for blasting are serviceable in cases where it is possible to obtain the assistance of workmen acquainted with their use. Means should be provided for packing the minerals collected in such a manner that they may be transported without shaking or rubbing against each other.

We will now suppose the voyager landing upon some coast, and desirous, among other things, either of adding to our knowledge of minerals or their localities, or of discovering ores of the useful metals or coal. With respect to many minerals and the ores of the metals, it fortunately so happens that precisely the same places may be searched, and these are cracks and fissures, or those dislocations of rocks known as faults, either partially or wholly filled with mineral matter. Should he see before him such veins as *a* and *b* traversing the rocks of a cliff, he should not neglect to land there. If any hollow spaces present themselves, let him there search for the crystalline minerals. The vein *a*

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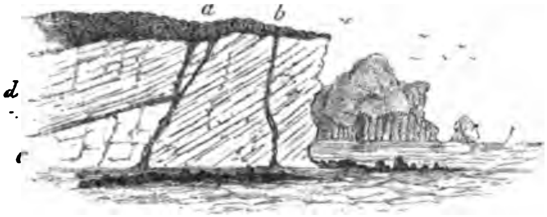
* Those who desire a further insight into the subject may consult Plattner's 'Art of Assaying by the Blowpipe;' Berzelius 'On the Blowpipe;' Scheerer 'On the Blowpipe;' and the above-mentioned work by Von Kobell; all of which are translated into English.



is represented as filling a fault, the dislocation having brought different rocks into contact; and we may suppose, for illustration, that *c* is porphyry, and *d* some schistose rock. The fissure *b* is intended to be a mere crack. Often when dissimilar rocks are brought into contact, mineral substances are found in the fissures, and this is a point which the voyager should not neglect. In certain countries the occurrence of the ores of the useful metals is not unfrequent under such conditions. On tidal coasts, should a vein of this kind be found productive, it may be desirable to wait for low water to trace the direction of the vein among any ledges or rocks which may be then laid bare. This may give the run of the vein inland, but not with certainty; for though fissures or faults may take general lines on the large scale, they, as would be expected, are very irregular for minor distances.

Should crystals be found in any such vein, it is often desirable to ascertain how they occur relatively to other bodies, crystalline or otherwise. Whole groups of crystals are thus frequently seen placed on certain projecting surfaces, facing one direction, and this as well on surfaces of crystals of other substances, as upon the sides of the vein, or *walls*, as they are technically termed. Such modes of occurrence are found as well in what, in common terms, may be called a horizontal as a vertical manner. They are not due to the drippings of water charged with the matter of the minerals in solution, such as are often seen in fissures, the resulting deposits being more or less crystalline according to conditions; on the contrary, the particular modes of occurrence to which we allude seem more the result of crystalline deposits from solutions (filling the whole or a large part of the fissure), so acted upon that projections in a given line, more especially if composed of certain substances, received these deposits—in fact much in the same manner as substances in solution may be thrown down by well-known methods when galvanic action is employed. We have before us an illustrative specimen from the Consols Mine, Gwennap, Cornwall, in which large crystals of quartz are on the one side covered by crystals of sulphuret of iron, and on the other by crystals of copper pyrites. Cases where crystals of one substance abundantly occur on one side of prior-formed crystals of another substance, and not on the reverse or opposite sides, are sufficiently common, and best seen in the fissures or mineral veins themselves.

Although, when exposed to the action of weather, the minerals which may be found in veins or fissures, open on the faces of cliffs, are not very often (except when of substances not easily injured) in a good state of preservation, they show that such minerals are found in the vein, so that, if time and opportunity permit, some unexposed part of the vein may be broken into. In such cases the process of blasting may often be employed with advantage. Success may not, certainly, always attend such a search, for it is curious to observe how very local, even in the same vein, the occurrence of a particular mineral may be.

In collecting minerals in a vein, should a boat be at hand, so that they may be readily taken to the ship, it is better not to limit the specimen to some mere crystal itself, but to break off some of the body (either part of the vein or of the rock, as the case may be) upon which it has been formed, so that, when more leisure may be obtained, any illustration the whole specimen may afford of the manner in which the mineral may have been formed should be preserved. By such specimens we often learn the history, as it were, of the mineral accumulations which, taken together, may, wholly or in part, have filled up a fissure. In this way it may often be seen that crystalline coatings of many substances have successively covered each other up towards the centre of the fissures.

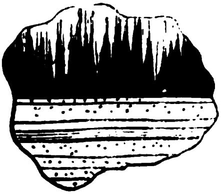
The contents of veins are far often from being definitely crystalline: thus quartz and other mineral substances, such as the ores of many metals, have an amorphous appearance, their deposit having been effected under conditions which did not permit them to crystallize. Again we find that, during the filling up of veins, fragments of rocks from the sides or upper parts of the fissure have dropped in; by their want of contact and by their isolation in many parts of the vein showing that this happened when the mineral or minerals thrown down from solutions were accumulating. A mineral vein sometimes forms a complete breccia, and this, as well from the cause just assigned, as from the mere filling up of the chinks left by fragments from the adjoining rocks, accumulated in the fissure before any deposit cf mineral matter from solutions was effected. As might be expected, both varieties are to be sometimes seen in the same vein. Ores of the useful metals, such as sulphuret of lead, copper pyrites, and peroxide of tin, may, and do, as well form the cementing matter of such fragments as quartz, carbonate of lime, or other minerals. In collecting some minerals which have covered others, it may be frequently desirable to obtain enough of the first to show how the latter may have occurred. Rock crystals are thus often seen investing other minerals, the most delicate threads of the latter being preserved in them. By a little care we may take out enough of the crystals to show completely how these threads may have radiated from a centre or have been otherwise disposed. By observing and recording the association and succession of minerals in veins, as Breithaupt has done in his 'Paragenesis der Mineralien, Freiburg, 1849;' and by the comparison of these with the experimental results obtained by De Sénarmont ('Annales de Chimie,' 3^e série, t. xxxii.), much information may be obtained respecting the manner in which mineral veins were produced.

As with other mineral substances, we find that ores of the useful metals have been sometimes thrown down in a fissure at one time and not at another, the deposit of one ore sometimes repeated, at others not. Thus there may have been a coating of a zinc ore at one time, of copper ore at another, and a covering of tin ore upon these, sometimes separated by other mineral substances, at others in deposits one above the other. Again, we find, in the successive dislocations which are sometimes seen to have effected the lines of fissures, that, while the lines of least resistance to the applied force have been chiefly through the contents of the original fissure, occasionally a new fissure has been made through portions of the adjoining rock; so that the minerals which may have been subsequently deposited in the new crack or fissure will be partly in the old line, and partly amid the newly-broken and adjacent rocks.

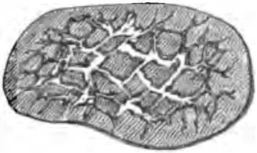
It would be out of place to attempt a general notice of those veins which, because they contain the ores of the useful metals, are commonly termed *mineral*: it will be sufficient to observe that from decomposition the upper or exposed parts of many do not show the ores in the manner they occur beneath. Thus, above veins wherein the ore from which the largest amount of copper is produced, namely, the compound of copper, iron, and sulphur known as *copper pyrites*, a mass of ferruginous matter is often found, known by many of our miners as *gossan*, and by the French miners as *chapeau de fer*. This is the result of a decomposition arising from exposure to atmospheric influences of various kinds, and occasionally from other influences. It is probable that the sulphur by a union with the needful oxygen became sulphuric acid, and that, this formed, the copper was attacked and removed, to be dealt with like any other solution of sulphate of copper. And beneath this gossan, or the *back of the lode*, as it is often termed, we observe appearances strongly reminding us of the common electrotype process for procuring copper from a similar solution. The pure metal is gathered together in chinks and cavities between the main mass of gossan and the body of the undecomposed copper pyrites, mingling, perhaps, occasionally with the lower part of the former. Sometimes this *native copper*, as it is called, may retain its metallic character, but at others it becomes converted into an oxide, and this again into a carbonate by the percolation of waters containing common air and carbonic acid. The iron seems in a great measure to have been left behind, and this forms the rusty substance above mentioned. It will be readily understood that, the needful conditions obtaining, other parts of a mineral vein than the mere upper portion may become decomposed in the same manner. In fact, the changes which have been effected in the fissures containing mineral veins, the mode of throwing down a mineral substance, its subsequent removal, its reappearance or apparent transport elsewhere, the pseudomorphous filling up of crystalline cavities, the substitution of one substance for another, the evident alterations produced by new fissures, particularly when these have traversed the original fissures at right angles, the differences of contents of fissures when they take different directions traversing the same country and association of rocks, are objects of high interest; and though no doubt best studied in mining countries, where opportunities are so numerous, and veins are so extensively laid open, a voyager, with some little time on a favourable portion of coast, may often nevertheless acquire much information on these heads. To do so, and procure illustrative specimens and a highly valuable collection, interesting in many respects, it is not necessary that the vein should be one containing the ores of the useful metals—the contents of those fissures and dislocations, termed common faults, are often in a scientific point of view equally important.

The cavities of many igneous rocks, and indeed holes and cavities in all, afford good places wherein to search for minerals. In some parts of Iceland (and also in the north of Ireland) it has been observed that crystallized minerals occur most abundantly in the cavities of the rocks which have suffered decomposition, the minerals having probably crystallized out of a solution of some of the constituents of the rock. In Iceland they are found sparingly in the cavities near the summit of the mountain Bulandstind, consisting of igneous rock, but very abundantly in those at its base (Sartorius v. Waltershausen, Skizze von Island, page 91). The traveller is recommended to observe the manner in which minerals are distributed at different heights in similar situations.

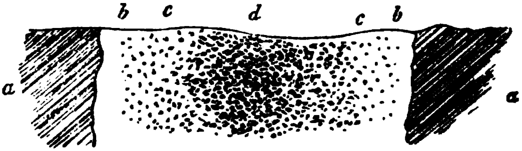
Minerals of the zeolite family are very common in the vesicular cavities of some igneous rocks; and at one time, before their mode of occurrence was properly understood, the quantity of water found in many of them was thought to militate against the igneous origin of the containing rock. They form an interesting class of minerals, and, opportunities offering, should always be collected. They come under the head of hydrated aluminous silicates, with potash, soda, lime, and their isomorphous substances. The great proportion of them contain from 8 to 18 per cent. of water in combination. In the same kind of vesicles, siliceous deposits in the form of agates are not uncommon. In these and in cavities of various rocks, even those of aqueous origin, such, for example, as the dolomitic rocks of the new red sandstone series, in Somerset and Gloucestershire, the agate linings of the cavities have continued only for certain distances, after which the elements of other minerals have entered the hollows, and various crystallized substances have been the result. Cavities, therefore, in all rocks may be searched. With respect to the successive siliceous coatings forming agates, while some kinds of coatings show an adjustment to the walls of the cavity, others have accumulated in flat layers, generally considered to have been formed horizontally. Sometimes part of a cavity has been filled in one way, and the remaining portion in the other. Occasionally, from cavities left after a part of the hollow has been filled horizontally, stalactites of the matter of the agate have descended from above, as in the annexed figure. It is desirable always to ascertain how far such flat layers correspond with the present horizon; and, if the vesicles or hollows are almond-shaped (elongated more in one direction than another), how far these are constant in the same direction, thus pointing out that in which the molten viscous rock moved.



Many nodules in rocks, those which have clearly not been formed as gravel or boulders by attrition, afford examples of the aggregation of similar matter from a mass, such as one of clay, in which that matter has once been more generally diffused. In this way we have siliceous nodules, calcareous nodules, and those valuable nodules, the clay ironstones. These last are fundamentally carbonates of iron, with a variable addition of the matter of the mud or silt amid which the carbonate of iron has once been more generally diffused. In many such nodules there has been a shrinking from the centre to the sides, causing cracks, that have been variously filled with mineral matter, as in the subjoined figure. Occasionally in the cracks so formed, and not quite filled up, various mineral substances are obtained well crystallized. It may be here observed, as regards the metallic titanium frequently discovered in iron furnaces when blown out, that we have found the oxide of titanium crystallized in the cavities of clay ironstones. Taken as a whole, the observer will do well to look into any cavities or cracks he may discover in rocks, even in the hollows among organic remains, for various mineral substances. Many a crystallized body will thus be frequently found, and the replacement of one substance by another be well seen.



Not only in cracks or hollows, but in the body of the rocks themselves, minerals may be observed well crystallized. This is well seen in the class of igneous rocks known as porphyries—that is, where a general paste or base, confusedly crystalline, compact or earthy, may happen to contain isolated and well-formed minerals of different kinds. From experiments in the laboratory, and the results of metallurgical and chemical operations carried on upon the large scale, we know that this isolation of crystals may readily be obtained. In the igneous *dykes*, as they are termed—that is, where igneous matter in fusion has been forced up, filling cracks formed in the rocks which they traverse—we sometimes see good illustrations of the mode in which isolated mineral crystals may be produced. Let us take as an example some of the granitic dykes known as *elvans* by the miners of Cornwall, and let the annexed figure represent a section of one of them, *a a* being some



schistose rock broken through or fractured (it may be any rock previously consolidated; granite is thus frequently fractured, and the fissure filled by an elvan). We find that, while the central portion *d* may be a granite, the parts *c c* are porphyritic, and *b b* some compact rock. Upon investigation, we see that all parts are chemically the same, and that these various characters are due to differences in cooling. The central portion retained its heat longest, while the portions adjoining the bounding and fractured rocks were more speedily cooled. In such porphyries various minerals are found, those of the felspar family being very common. Such results from differences of cooling can be imitated artificially with substances under our control. In this way crystals of silicate of lime may be beautifully obtained, isolated in transparent glass.

Whole mountain masses are occasionally composed of porphyritic rocks, including the porphyritic granites among them; and it is desirable to obtain specimens of these, selecting portions where the crystals may be well formed, and observing, should more than one kind of isolated mineral be present, how far when one kind becomes common another may disappear, and if different kinds continue mixed through the general mass, or only in patches. It is equally desirable to obtain good characteristic specimens of the base or paste, and from situations where they have been uninjured by exposure to the weather, and have lost little of the soluble substances which may have once been contained in the rock. The chemical study of the whole of such igneous rocks is every day becoming more interesting.

It is not only among the igneous rocks which have once been in a molten state that the observer should look for minerals, but also, in volcanic regions, for those evidently sublimed upon the faces of craters, or in cracks or chinks of their sides, or of lava currents. For an example of the kind of observations to be made in volcanic districts, and the method of drawing conclusions from them respecting the condition of the interior of the globe, and the changes to which its solid crust has been exposed, the reader is referred to the 'Physisch-geographische Skizze von Island, Göttingen, 1847,' and the work entitled 'Ueber die vulkanischen Gesteine in Sicilien und Island und ihre submarine Umbildung von W. Sartorius von Waltershausen: Göttingen, 1853.'

The minerals often seen isolated in those rocks which have been termed metamorphic, or altered, in consequence of the upburst or protrusion of some rock in a state of igneous fusion near them, constitute a class of much interest. Here again we see conditions highly favourable to the crystallization of minerals; but this case so far differs from that of the porphyries, that, whereas in the latter the whole mass has evidently been in a fluid or viscous state, in the former the stratified character of the rocks of that class is preserved. The manner of observing this order of rocks belongs to geology. It is only necessary here to call attention to the kind of isolated minerals found. Among them staurolites, andalusites, and garnets are frequent under certain conditions, which it may be advisable to guard the observer from supposing merely those of temperature. The freedom with which the isolated minerals thus formed, have crystallized, the main mass retaining its general structure, is highly interesting. We have seen crystals of garnet, perfectly formed, amid the grains of a sandstone, close in contact with granite, the beds of the sandstone retaining their original shape, and the mechanically-produced grains well distinguishable. In many districts the order in which some of these minerals occur, as we recede from the igneous rock, is said to be invariable. In order, if possible, to discover how far such an order of succession either exists, or is the same, for different localities, the relative distances from the igneous rock, at which the different species are found to occur most abundantly, should be carefully recorded.

Minerals from inaccessible localities are often found in the moraines, ancient as well as recent, brought down by glaciers, and also in watercourses. The rubbish heaps in the neighbourhood of mines frequently contain rare crystallized minerals resulting from the decomposition of metallic ores by exposure to the atmosphere, as well as unaltered minerals.

Gold occurs sometimes disseminated in rocks and sand, in particles too minute to be easily detected by the eye. If the sand, or the rock reduced to powder, be rubbed in a mortar with a little mercury, an amalgam of gold and mercury is formed which may be separated by washing away the stony powder. On exposing the amalgam to heat in an iron or earthen crucible, the mercury will be driven off, leaving the gold behind.

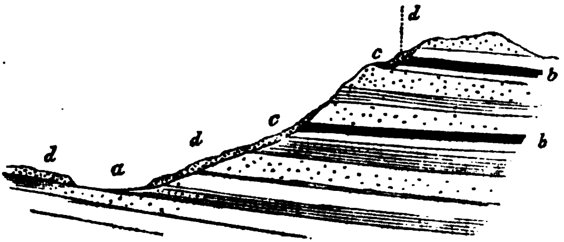
We have chiefly referred hitherto to minerals found crystallized, either alone or entangling some other substances. Many important mineral substances occur, so that they appear to us in mass, sometimes forming beds mingling with others, or occupying clefts in rocks; occasionally constituting portions which have separated out from the body of the rock, as in the instances of the nodules previously mentioned. In these various forms many minerals are found, some being ores of the useful metals, such as iron ores, including bog-iron among them, and iron pyrites, valuable for the sulphur in it. As filling clefts in rocks, mingled with other matter, many ores of lead, tin, copper, &c. Other substances, also employed for various purposes, are obtained in the massive state, such as rock-salt, gypsum, and coal. For these minerals qualitative chemical researches will be found valuable, it being desirable to test the composition of many substances, which may offer certain general resemblances in appearance, before some given locality may be quitted.

Among the minerals occurring in beds, we should more particularly notice coal and other substances of that class, which have of late become so important for the extension of steam navigation. Our shipping daily bring home specimens of coal or lignite from localities where they were not previously known to occur. And it may be here needful to state, as now well known to geologists, that good coal is not confined to rocks of a particular geological date, but that, the needful physical conditions having obtained, it has been produced from vegetable mätter accumulated at different geological times. When we have a cliff before us, there is little difficulty in seeing that a coal-bed occurs among others of sandstone, shale, or other substances. Not unfrequently coal-beds are based upon clays, or argillaceous strata which have a clayey character from exposure, and then it sometimes happens, from the slipping and falling of the general mass, that the real thickness and importance of a coal-bed may not appear on a cliff. Thus it was at Labuan, where now a valuable coal-bed about nine feet thick is worked: when first seen on the coast it did not appear more than eighteen inches thick.

Of whatever geological age an accumulation of mud, silts, sands, and gravels, now more or less consolidated as shales, sandstones, and conglomerates, and containing interstratified coal, may happen to have been, it rarely occurs that the bed upon which the coal itself reposes has not some peculiar character, easily observed. In many cases we feel assured that this has arisen from these beds having formed the ground, often perhaps marshy or with a slight covering of water, on which the plants, now converted into coal, have grown. Should these marked deposits be found, they often form valuable aids in tracing coal-beds, where the outcrop of the latter may not be very apparent, and they are especially serviceable, as in many of the hilly coal-measure districts of the British Islands, where these beds throw out springs of water. Whole lines of such springs coinciding with the bottom of coal-beds can be traced in the hilly coal districts of South Wales and Monmouthshire, and often on a hillside faults traversing the general mass can be as well seen, where these lines are interrupted, as if a diagram section were before us.

In some of the beds immediately subjacent to the coal peculiar fossil plants are found. In the palæozoic coal of the British Islands a fossil plant, named *Stigmaria ficoides*, is very characteristic. Peculiar fossil plants, not the one mentioned, are discovered, it is thought, well marking the beds on which the coal-beds rest in the Burdwan coal district in India, and other instances of a similar kind are recorded. It will be obvious that, although the conditions for the production of marked accumulations may have preceded the growth of most of the coal-vegetables themselves, the latter may not have sometimes grown, so that no coal rests upon such beds. Still these beds, when any such occur, are useful to trace, since, while we find in one locality no vegetable accumulation to have taken place upon them, or, if effected, the vegetable matter to have been subsequently removed, upon an extension of the same beds we may often see good workable coal.

Though in cliffs, either on the shore, or on the sides of rivers, hills, and mountains, we commonly find the most direct evidence of the existence of coal, it may be often traced to its beds, where such occur, by means of the detritus brought down by brooks and rivers. By following rolled pebbles up such watercourses they may be often seen to end near some bed or beds whence they have been derived. If these cross the stream, a good opportunity may be afforded for examining their quality and thickness. The pebbles may, however, come from the sides of some adjacent hills sloping towards the streams, the beds of coal not crossing them, fragments only of their outcrop being mingled with any others of associated beds. The thickness of such coal-beds may be thus concealed, as will be readily seen by the annexed section, in which *a* represents the river course, up which pebbles of coal may be traced; *b b* beds of coal, the outcrops of which, *c c*, may be much concealed by fragments of rock descended from above and mingled in a fragmentary covering *d d*. The best should be done to obtain a knowledge of the associated beds by tracing up the rills of water descending the sides of the hills. Excellent evidence may thus be often obtained, and the true position of the coal-beds found. In selecting specimens of coal in such cases, it rarely happens that a portion of it can be procured fairly exhibiting its qualities, injury having arisen from atmospheric influences. If the outcrop of the coal can be attained, it is always desirable to penetrate as far as circumstances will permit into the body of the bed, thence selecting a fair specimen. When this cannot be done, and a voyager often has but little time for his researches, fragments lying about should be selected which may appear the least decomposed; and if these be different qualities, as if of portions of



different beds, they also should receive attention. In all cases where fossil plants are mingled with the coal or associated beds, specimens as various as can be obtained should be secured. These have a geological bearing which may often turn out of great practical importance in some given region.

It scarcely requires remark that the foregoing observations are but hints which it is hoped may be useful to those engaged in voyages of discovery and survey, or who, on more general service, may feel inclined, whenever fitting opportunities may present themselves, to devote some portion of the time not occupied by their professional duties, to the study of minerals, either for purely scientific purposes, for their useful employment, or for both combined. That these opportunities do present themselves we well know, or rather if sought will be found more frequently than might be imagined. Many a walk along a coast may thus be advantageously turned to account, and an interest be excited not at first thought probable. Not only may a naval man thus add to his own stock of knowledge, but he may most materially by his exertions promote the advance of science and its applications generally, minerals being objects of great interest, whether we regard them with reference to their importance to man, and the aid many of them afford to the spread of civilization, or as connected with several sciences, even those of the highest order.

ARTICLE XIII.

FOURTH DIVISION, SECTION 3.

ON OBSERVATION OF EARTHQUAKE PHENOMENA.

BY R. MALLET, Mem. Ins. C.E., F.R.S., M.R.I.A.

THE observation of the Facts of Earthquakes and the establishment of their theory constitute *Seismology* (from *σεισμος*, an earthquake, a movement like the shaking of a sieve), which has only become an exact science within the last twelve years. Its immediate and most important applications are to the discovery of the nature of the deep interior of our planet, and of the reactions of the interior upon the exterior, visible in volcanic action at the surface.

Whenever a blow or pressure of any sort is suddenly applied, or the passive force of a previously steady or slowly variable pressure is suddenly either increased or diminished, upon material substances, all of which, whether solid, liquid, or gaseous, are more or less elastic, then a *pulse* or *wave* of force, originated by such an *impulse*, is transferred, through the materials acted on, in all directions, from the *origin* or *centre of impulse*, or in such directions as the limits of the materials permit. The transfer of such an *elastic wave* is merely the continuous forward movement, of a change in the relative positions, a relative displacement and replacement, of the integrant molecules or particles of a determinate volume, affecting in succession the whole mass of material.

Ordinary sounds are waves of this sort in air. The shaking of the ground felt at the passage of a neighbouring railway-train is an instance of such waves in solid ground or rock. A sound heard by a person under water, or the shock felt in a boat lying near a blast exploded under water, are examples of an elastic wave in a liquid.

The velocity with which such a wave traverses, varies in different materials, and depends principally in any given one, upon the degree of elasticity and upon the density. This *transit period* is constant for the same homogeneous material, and is irrespective of the amount or kind of original impulse: for example, in air its velocity is about 1140—in water about 4700—and in iron probably about 11,100 feet per second—all in round numbers. In crystallised or pseudo-crystalline bodies, such as laminated slate or other rocks, the transit period may vary in three different directions. A very great retardation of this period is produced in solids whose mass is shattered or broken, even when the fissures appear perfectly close.

Thus, if one stand upon a line of railway near the rail, and a heavy blow be delivered at a few hundred feet distant upon the iron rail, he will almost instantly hear the wave through the iron rail—directly after he will feel another wave through the ground on which he stands—and, lastly, he will again hear another wave through the air; and if there were a deep side-drain to the railway, a person immersed in the water would hear a wave of sound through it, the rate of transit of which would be different from any of the others—all these starting from the same point at the same moment.

The size of such a wave—that is, the volume of the displaced particles of the material in motion at once, depends upon the elastic limits of the given substance, and upon the amount or power of the originating impulse. By the *elastic limit* in solids is meant the extent to which the particles may be relatively displaced without fracture or other permanent alteration: thus glass, although much more perfectly elastic than India rubber, has a much smaller elastic limit.

Nearly all such elastic waves as we can usually observe, originate in impulses so comparatively small that we are only conscious of them by sounds or vibrations of various sorts, the advancing forms of whose waves are imperceptible to the eye; but when the originating impulse is very violent, and the mass of material suddenly acted on very great, as in an earthquake, the size of the wave may become so great as to produce a perceptible undulation of the surface of the ground, often visible to the eye; and by whose transit bodies upon the earth are disturbed (chiefly through their own inertia), thrown down, &c.

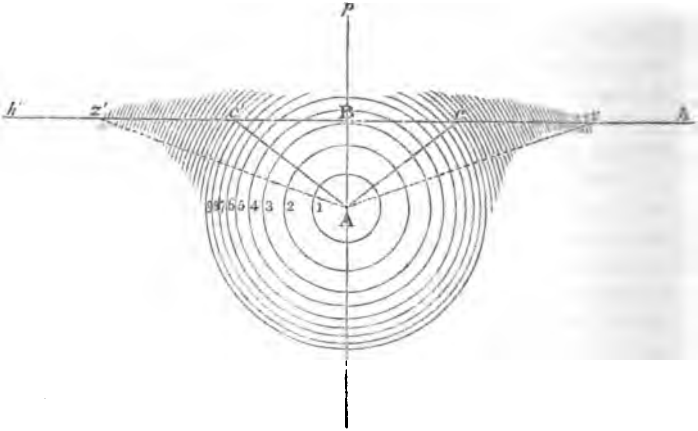
There is every reason to consider it established, that an earthquake is simply "*the transit of a wave or waves of elastic compression in any direction, from vertically upwards to horizontally in any azimuth, through the crust and surface of the earth, from any centre of impulse or from more than one, and which may be attended with sound and tidal waves, dependent upon the impulse and upon circumstances of position as to sea and land.*"

Until this was clearly grasped, the observation of earthquake phenomena, in the absence of a "guiding hypothesis," was vague and useless.

At present the objects and aim of *Seismology* are of the highest interest and importance to geology and terrestrial physics. It offers to us the only path to discover the real constitution and condition of the interior of our planet, and will become the key to open to us the true nature, depth of origin, and source, of volcanic heat. In these respects, one of the most primary objects of *Seismometry* is to arrive at a knowledge of the depth beneath the earth's surface from which earthquake shocks are delivered, i. e. the depth of the *origin*.

The observer must form clear conceptions of the fundamental conditions of propagation of seismic waves. Fig. 1 represents a vertical section of part of the earth in the plane of a great circle, cutting the surface at *h'h* and passing through the origin of impulse at A—A*p* being the prime vertical to that point whose depth beneath the surface is BA. The wave starts from the origin (assuming the earth's mass homogeneous) with one normal and two transversal vibrations; neglecting the latter for the present, the wave may be imagined transferred outwards, in all directions in concentric spherical shells, whose volume at the same phase of the wave is constant. The interval between any two such shells therefore diminishes as r^2, r being the mean radius, and the overthrowing energy of the shock in the direction of r varies inversely as the square of the distance from the origin.

Fig. 1.



The shock reaches the surface at B directly above the origin vertically, but, for all points around that, it emerges with angles getting more and more nearly horizontal as the distance measured on the surface increases. The intersecting circle of any one shell with the surface, which is that of simultaneous shock, is the *coseismal line*, or crest of the earth-wave; circular (like the circles on a pond into which a stone has been dropped) if in a homogeneous medium, more or less distorted if in a heterogeneous one, such as constitute the various formations of the earth, but always a closed curve. The transversal vibration is transmitted outwards in the normal direction (*Ac*) more slowly than the normal one, which is one cause of the small jarring impulses often felt after the great shock. (For more complete information as to the physical and mathematical conditions, see 'Jamin, Cour de Physique, 1858,' 9th and 10th chapters; Rankine's 'Applied Mechanics,' chap. iii., sec. 1, and chap. v., sec. 4 and passim; Dr. Young's Lectures, 'Nat. Phil.,' passim, but especially lectures 8, 13, 31, 49, and 50; Herschel, Art. Sound, 'Encyc. Metrop.;' Hopkins, Report, 'Brit. Ass. Trans.,' 1847-48; Mallet's Fourth Report, Facts and Theory of Earthquakes, 'Brit. Ass. Trans.,' 1857-58.)

Observers in earthquake countries should make themselves familiar with the usual features, succession of events, and concomitants which with a certain sort of regularity apply to all earthquakes. Mr. R. Mallet's 'First Report upon the Facts of Earthquakes,' Trans. Brit. Ass. for 1850, gives these in a condensed and systematic form. The greatest shocks are not the most instructive, except as to secondary effects; but every great shock is usually followed by several smaller—the first should therefore be viewed as a "notice to observe" the latter carefully. Earthquakes must not be confounded, either with the forces producing *permanent* elevations of the land, or with these elevations themselves. "An earthquake, however great, is incapable of producing any permanent elevation or depression of the land whatever (unless as secondary effects); its functions of elevation and depression are limited solely to the sudden rise, and as immediate fall, of that limited portion of the surface through which the great wave is actually passing momentarily." The one class of phenomena must be held as distinct from the other as the rise and fall of the tide is distinct from the momentary and local change of sea-level produced by the waves of its surface.

The phenomena of every earthquake may be divided into—1st. *Primary*, or those which properly belong to the transit of the wave or waves through the solid or watery crust of the earth, the air, &c.; 2nd. *Secondary*, or the effects produced by this transit—and both must be kept distinct from co-existent forces, such as those of volcanic eruption, permanent elevation or depression of land, &c., which, however closely they may be connected, with the originating impulse of the earthquake, form no true part of it—though they usually complicate its phenomena.

The *centre of impulse*, or *origin* of earthquakes, is generally conceived to be at and due to, a sudden volcanic outburst, or sudden upheaval or depression of a limited area, or sudden fracture of bent and strained strata, or probably to the sudden formation of steam from water previously in a state of repulsion from highly heated surfaces (spheroidal state), and which may or may not be again suddenly condensed under pressure of sea-water, or possibly to the evolution of steam through fissures and its irregular and *per saltum* condensation under pressure of sea-water. This origin should be carefully sought for as to its nature and position.

An earthquake may have its *origin* either *inland* or *at sea;* and as this may be, a different set of phenomena will present themselves. In the former case we may expect, in the following order—1st, The *Great Earth-wave*, or *true shock*, a real roll or undulation of the surface travelling with immense velocity outwards in every direction from the point vertically above the centre of impulse. If this be at a small depth below the surface, the shock will be felt principally horizontally; but if the origin be profound, the shock will be felt more or less vertically; and in this case also we *may* be able to notice two distinct waves, a greater and a less, following each other very rapidly: the first due to the originating normal wave, the second to the transversal waves vibrating at right angles to it. If we can find the point of the surface vertically over the origin, and the direction of emergence of the shock at a distant point, or the angles of emergence at two distant points, neither of which is vertically over the origin—*i. e.* in one coseismal line—we can find the depth of the origin from the surface by methods pointed out in Mr. Mallet's Fourth

Report on Facts and Theory, &c., 'Brit. Ass. Trans.,' 1857-58, but which space will not permit of transcript here.

An erroneous notion of the dimensions of the great earth-wave must not be formed from its being called an undulation—its *velocity* of translation upon the earth's surface is great occasionally, in hard, elastic, and unshattered, formations, probably as much as thirty miles per minute, and the wave or shock moving at this rate has been recorded to have taken some seconds to pass a given point; if so, its *length* or *amplitude* is often several miles. Its *altitude*, however, is not great, and, as may be seen from Fig. 1, continually diminishes as the wave passes outwards from the origin.

Before, during, or immediately after the passage of the great earth-wave or main undulation, a continuous violent tremor or short quick undulation (like a short chopping sea) is often felt. This may arise from secondary elastic waves accompanying the great earth-wave (like the small curling or capillary waves on the surface of the ocean swell), produced probably by comparatively minute or secondary impulses, due to the discontinuous and heterogeneous nature of the formations through which the normal wave has been propagated. Sometimes, however, a number of shocks occur so rapidly as to convey the impression of a continuous jar or tremor, and may be succeeded by one or more *great* shocks; this is probably the source of "tremor observed before the shock," as the subsequent arrival of the transversal waves is of the tremors after it. (For other complications of the phenomena, see Mallet's 1st, 2nd, and 4th Reports, Brit. Ass.) It is very desirable that the interval in time between these minor oscillations should be observed by a seconds watch, and also their total duration at each epoch of motion. Former narrators often confound the whole of each epoch of such rapidly recurrent shocks, with one shock supposed to last a considerable time.

2nd. When the superficial undulation of the earth-wave, coming from inland, reaches the shores of the sea (unless these be precipitous, with deep water), it may lift the water of the sea up and carry it along on its back, as it were, as it goes out into deep water; for the rate of transit is so great that the elongated heap of water lifted up has not time to subside laterally. This may be called the *forced sea-wave;* its elevation will be comparatively small, and a little less than the altitude of the earth-wave, when close to the shore on a sloping beach; and where the water is still, any observations that can be made as to the height of this fluid ridge will afford rude indications of the altitude of the earth-wave or shock.

Earthquakes, whether at sea or on land, seem to be only accompanied with subterranean noises when strata are fractured or masses of matter rent or blown away at volcanic origins. Where such is not the case, the two preceding are the only waves to be expected from an earthquake of inland origin; but when fracture occurs, then at the moment of the shock, or very slightly before or after it, we shall hear, 3rd, the *Sound-wave through the earth;* and at an interval longer or shorter after this, 4th, the *Sound-wave through the air.*

Again, when the origin of the earthquake is under the sea (and such seems to be the case with many great earthquakes), we may expect in the following order—1. The great earth-wave or shock; 2. The forced sea-wave, which is formed as soon as the true shock or coseismal undulation of the bottom of the sea gets into shallow water, and forces up a ridge of water directly above itself, which accompanies it to shore, and which seems to be the cause of that slight disturbance of the margin of the sea often noticed as occurring at the moment of the shock being felt; 3. The sound-wave through the earth (as in the former case); 4. The sound-wave through the sea, which arrives after that through the earth, but prior to, 5. The sound-wave through the air. Where the originating force is not a single impulse, but a quick succession of these, or a single impulse extending along a considerable line of disturbance, passing away from the observer, the sound-waves will be rumbling noises, and may be confounded in each medium more or less; and where no fractures or explosions occur, the sound-waves may be wholly wanting.

Lastly, and usually a considerable time after the shock, the *great sea-wave* rolls in to land. This is a *wave of translation*: a heap of sea water is thrown up at or over the origin of the earthquake by the actual disturbance of the sea-bottom, or in the direction, and by the emergence, of the earth-wave beneath the sea at a large angle to the horizon, and begins to move off in waves like the circles on a pond into which a pebble is dropped; and its phenomena depend upon laws different from any of the other (elastic) waves of earthquakes.

The original altitude (above the plane of repose of the fluid) and volume of this *liquid wave* depend upon the suddenness and extent of the originating disturbance, and upon the depth of water above its origin. Its velocity of translation on the surface of the sea varies with the depth of the water at any given point, and its form and dimensions depend upon this also, as well as upon the sort of sea-room it has to move in. In deep-ocean water one of these waves may be so long and low as to pass under a ship without being observed; but as it approaches a sloping shore its advancing slope becomes steeper, and when the depth of water becomes less than the altitude of the wave, it topples over, and comes ashore as a great breaker. Sometimes, however, its volume, height, and velocity, are so great that it comes ashore bodily and breaks far inland. The direction from which it arrives at any given point of land does not necessarily infer that in which the origin may be; as this wave may change its direction of motion greatly, or become broken up into several minor waves in passing over water varying much and suddenly in depth, or in following the lines of a highly-indented or island-girt shore. (See Airy on Tides, Encyc. Metrop.; Russel, Report on Waves, Brit. Ass. 1844; Bache, Great Sea Waves in Pacific, Amer. Jour. Science, vol. xxi., 1856; Mallet, 4th Report, 1857-58; Darwin, Voyage of the Beagle.)

Observations of each of these classes of waves which we have thus briefly described may be made either directly by the aid of instruments, specially provided or extemporaneously formed, or indirectly by proper notice of certain effects which they produce on objects upon the earth's surface.

Direct observations by complete self-registering Seismometers do not come within our present scope. They will be found treated of at large in Mallet's 4th Report, Brit. Ass. 1857-58, where the principles, construction, methods of observation, and applications of the best known instruments are described.

Whatever instruments be employed, however, it is found that perturbations in the main directions of emergence at the surface, of the normal earth-wave, due principally to heterogeneity of structure in depth, and to inequality of surface, are such as to render a special choice of district necessary, in attempting any seismometrical researches (even with perfect instruments) having in view the determination of the position of the origin or focus of disturbance. This choice, according to our present knowledge, must be determined by the following conditions:—

1. The whole surface-area of observation, must be as far as possible, uniform in geological structure, and so, to as great a depth as possible. If of stratified rock, not greatly shattered and overthrown, but (viewed largely) level or rolling only. The harder and more dense and elastic the formation, the better, but neither intersected by long and great dykes or igneous protrusions of magnitude, nor suddenly bounded by such formations.

2. The surface must not be broken up into deep gorges, and rocky ranges, and valleys. Seismometry, in a high and shattered mountainous country, can scarcely lead to any result but perplexity. If the surface be deeply alluvial all over, it is less objectionable than valley-basins and pans of deep alluvium, with rocky ribs between them.

3. The size of the area chosen for observation must bear a relation to the force of the shocks experienced in it. *Moderate shocks* are always best for observation, and in

large areas of the *most uniform character of formation and surface* will give the most trustworthy indications.

4. If several seismometers are set up in the area, they should be all placed on corresponding formations, either all on rock, or all on deep alluvium. The rock, when attainable, is always to be preferred. Three seismometers, at as many distant stations, will be generally found sufficient, if the object be chiefly to seek the focal situation and depth.

We, therefore, proceed to observations with extemporaneous instruments, on the earth-wave or shock. The elements necessary to be recorded are such as will enable us to calculate—1. The direction in azimuth of the wave's motion upon the earth's surface; and also its direction of emergence at the points of observation. 2. Its velocity of transit upon the surface. 3. Its dimensions and form—*i.e.* its amplitude and altitude.

If a common barometer be moved a few inches up and down by the hand, the column of mercury will be found to oscillate up and down in the tube in directions opposite to the motions of the instrument, the range of the mercury depending upon the velocity and range of motion of the whole instrument. A barometer fixed to the earth, therefore, if we could unceasingly watch it, would give the means of measuring the vertical element of the shock-wave; and if we could lay it down horizontally, it would do the same for the amplitude or horizontal element. This we cannot do; but the same principle may be put into use by having a few pounds of mercury, and some glass tubes bent into the form of L, sealed close at one end, and open at the other; the bore being under two-tenths of an inch in diameter, and each limb about fifteen inches long. We shall also require some common barometer tubes of the same calibre: the open end being turned up like an inverted syphon, and equal in bore to the rest of the tube. (See *Fig.* 5.) The L tubes are used for the horizontal, the others for the vertical elements.

To fit the L tubes for use, fill each partly with mercury, and so adjust it that a column of five inches in length shall be in each limb of each tube, when held as in *Fig.* 2; the limb *a b* horizontal, and the vertical column being supported as in a barometer. Tie four of these tubes so prepared together, back to back, so that if one horizontal limb face the north, the others shall face east, south, and west respectively, as in *Fig.* 3. In this position secure them all down upon a broad stout board, that can be itself fixed to a surface of rock, or other fixed surface of the earth.

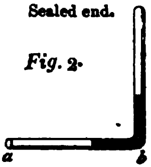


Fig. 2.

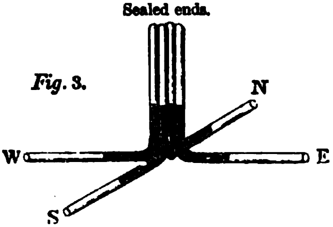
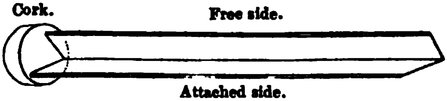


Fig. 3.

An index or marker must now be prepared for each tube; for one of these cut a common piece of card two inches long by rather less than two-tenths of an inch wide, nick it partly through along a centre longitudinal line, and double it down the long way, so that the two segments shall stand at rather less than right angles to each other; cut a cylindrical slice of cork one-eighth of an inch thick, of a diameter such that it will go easily into the tubes: attach the bit of cork with glue or sealing-wax to the end of *one* wing or segment of the folded card, leaving the other free, and thrust the whole into the horizontal limb of the tube until the cork just touches the mercury, and so for the others. This marker is shown at rather more than full size in

Fig. 4.



The edges of the card having a certain amount of elastic extension, must slightly grip the inside of the tube.

It will now be found, if horizontal motion be given to the system of four tubes—say, from south to north—that the marker in the southern tube will be pushed southwards a certain space by the movement of the mercury, and will remain to point out the space when the mercury has returned to rest. If the motion be in some direction between two adjacent tubes—say, from south-east to north-west—the markers in the south and east tubes will both show a certain motion, equal in this case, but in others with a certain ratio to each other, by which the direction between the cardinal points may be calculated.

For the vertical element: let the barometer-tube, *Fig.* 5, be filled with mercury, so that about six inches shall stand in the open end *a*, into which thrust a marker, as in *Fig.* 4, and about twelve inches in the sealed limb; place this vertically, and secure it to a fixed mass of rock, a heavy low building, or large tree; from the amount to which the marker is found moved up in the tube the altitude of the wave may be found; and it is obvious, that by the conjoint indications of the four horizontal tube-markers and this vertical one, the direction of emergence of the wave is determinable.

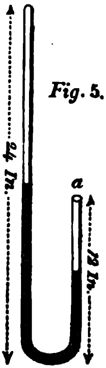


Fig. 5.

These instruments are of the nature of fluid pendulums, their use assumes the velocity of the earth-wave constant, and, in common with all pendulums, they have certain disadvantages as seismometers. (See Mallet, 4th Report Brit. Ass.) If

$$T = \pi \sqrt{\frac{l}{g}}$$

be the time of oscillation of any solid pendulum whose length is l, then

$$T = \pi \sqrt{\frac{l}{g\,(\sin a + \sin a')}}$$

will be the time of oscillation of any such fluid pendulum, a and a' being the angles of inclination of the limbs of the tube to the horizon. Where these are parallel and vertical, $\sin a = \sin a' = 1$ and

$$T = \pi \sqrt{\frac{0 \cdot 5 \times l}{g}}$$

They are much superior to common solid pendulums, where the dimensions of the shocks are small; but where these are great and very violent, heavy solid suspended pendulums will be found more applicable: the length of the seconds pendulum for lat. Greenwich will always be desirable. Where fluid pendulums are not attainable, a solid pendulum to answer some of the purposes may be thus prepared :—Fix a heavy ball, such as a four-pound shot, at one end of an elastic stick, whose direction passes through the centre of gravity of the ball: a stout rattan will do. Fix the stick vertically in a socket in a heavy block of wood or stone, and adjust the length above the block as near as may be to that of the seconds pendulum for Greenwich. Prepare a hoop of wood, or other convenient material, of about eight inches diameter; bore four smooth holes through the hoop in the plane of its circle, and at points ninety degrees distant from each other: adjust through each of these a smooth round rod of wood (an uncut pencil will do well), and make them, by greasing, &c., slide freely, but with slight friction through the holes.

Secure the hoop horizontally at the level of the centre of the ball by struts from the block, and the ball being in the middle of the hoop, slide in the four rods through the hoop until just in contact with the ball.

It is now obvious that a shock, causing the ball to oscillate in any direction, will move one or more of the rods through the holes in the hoop, and that they will remain to mark the amount of oscillation.

A similar apparatus, with the pendulum-rod secured horizontally (wedged into the face of a stout low wall, for example), will give the vertical element of the wave. Two of these should be arranged, one north and south; the other east and west. One objection to this and all apparatus upon the same principle is, that as the centre of elastic effort of the pendulum rod never can be insured perfectly in the plane passing through the centre of gravity of the ball, for every possible plane of vibration, so an impulse in a single plane produces a conical vibration of the pendulum, and hence the ball deranges the position, more or less, of the index rods which are out of the true direction of shock. Moving the apparatus by hand, and a little practice in observation of its action, will, however, soon enable a pretty accurate conclusion as to the true line of shock to be deduced from it.

It will be manifest that the observer must record minutely the dimensions and other conditions of such apparatus, where not permanently kept, to enable calculations as to the wave of scientific value to be made from his observations of the range of either fluid or solid pendulums.

A common bowl partly filled with a viscid fluid, such as molasses, which, on being thrown by oscillation up the side of the bowl, shall leave a trace of the outline of its surface, has been often proposed as a seismometer. This method has many objections: it can only give a rude approximation to the direction of the horizontal element; but as it is easily used, should never be neglected as a check on other instruments. A common cylindrical wooden tub, with the sides rubbed with dry chalk and then carefully half filled with water or dye-stuff, would probably be the best modification.

Another extemporaneous instrument for measurement of vertical motion in the wave may be sometimes useful. Make a spiral spring of eighteen inches or so in length by twisting an iron wire of one-eighth of an inch diameter round a rod of about 1¼ inch diameter (the staff of a boarding-pike); suspend it by one end vertically from a fixed point, and fix a weight (a twelve-pound shot will do) to the lower end, and below and in a line passing vertically through the centre of gravity of the weight fix the stem of a common tobacco-pipe; let the lower end of this stem just dip into a deep cup filled with pretty thick common ink or other coloured fluid: the action of this needs no description.

The preceding instruments suffice at once to give the direction of transit of the earth-wave and its dimensions: its rate of progress or transit over the shaken country remains to be observed, and wherever it may be possible to connect three or more such instruments as have been described, at moderately distant stations, say 15 to 30 miles apart, by galvanic wires, so as to register at one point the moment of time at which each instrument was affected, the best and most complete ascertainment of transit rate may be expected. Galvano-telegraphic arrangements of the simple character required are become familiar, and are easily set to work. The best seismometer to which they can be applied (for voyagers) is that described in Mallet's 4th Report, &c., p. 87, and plate xv.; and no surveying ship proceeding to earthquake regions should be unprovided with three such seismometers and the requisite time-recording apparatus.

A still simpler form of rough seismometer suited to the resources of distant and isolated observers remains to be described. It depends upon principles altogether different from those already mentioned, and is most applicable to seismic districts where the angle of wave emergence is not steep—*i.e.* where shocks are usually nearly horizontal.

Every body overthrown by an earthquake shock is upset by its own inertia causing it to move in the opposite direction to that in which the ground has moved under it. Thus a wall falls towards the S. if the shock passes across its length from S. to N., and if any such homogeneous parallelopiped or right rectangular prism, standing on end upon a level surface, be so upset by its own inertia, the supporting surface being suddenly moved beneath it, in the direction of its own plane (as by the horizontal component of an earthquake shock), it may be shown that the velocity of the surface must be

$$V^2 = \frac{4}{3} g \sqrt{a^2 + b^2} \times \left(\frac{1 - \cos \theta}{\cos^2 \theta}\right)$$

where a is the altitude of the solid, b its diameter of base or thickness, and θ the angle formed by the side, and a line drawn through the centre of gravity to the extremity of the base and $V = 2\,g\,h$. This velocity is independent of the density or material of the solid, because the oversetting force, being its own inertia, is always proportional to the density.

This is the foundation of all accurate and useful observation of dislocated and overthrown buildings in countries that have suffered by earthquake, and by which not only may the direction of (the horizontal component of) the earthquake shock be obtained, but a close approximation made to its velocity.

With a given velocity, V, therefore, it is possible to assign the dimensions a and b, such that the solid shall *just overset*, and with this velocity a similar solid, but having θ greater, shall remain unmoved; assuming always, that friction against the supporting surface gives sufficient adhesion to prevent sliding.

If in place of a square prism, such as a wall, the solid be a right cylinder like a column, the diameter of its base being b, then

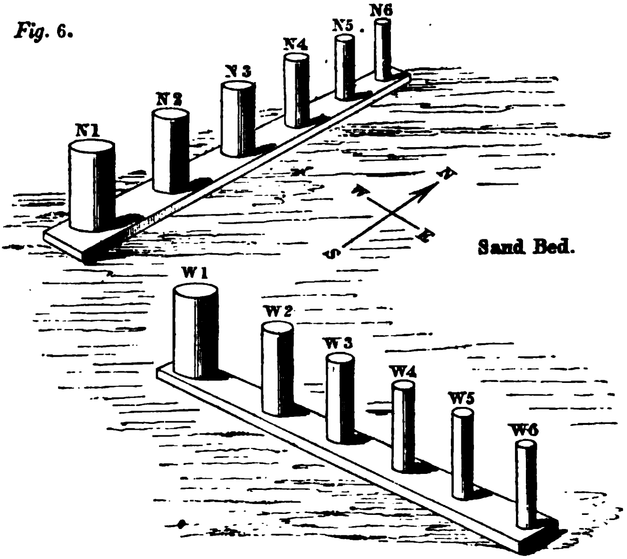
$$V^2 = \frac{15\,b^2 + 16\,a^2}{12\,a^2} \times g\,\sqrt{a^2 + b^2}\,(1 \dot{-} \cos\theta).$$

This gives the means of constructing a seismometer of great simplicity, that (in the absence of better means) shall give the horizontal velocity of shock within a narrow limit of error.

Let there be constructed two similar sets of right cylinders—say, each set six to twelve in number—all of equal height (a) and of the same sort of material, but varying in diameter in each set, with a uniform decrement from the greatest to the least.

Convenient dimensions for earthquake observations of *mean* intensity will be such that the cylinder of largest diameter shall have its altitude equal to three diameters, or $b = \frac{a}{3}$; and that the cylinder of least diameter shall have its diameter one-third of that of the greatest one, or $b = \frac{a}{9}$. Any number of cylinders of intermediate diameters may be interpolated between, and the greater the number

Fig. 6.



the more accurate the instrument becomes. A series of six to ten in each set will, however, be sufficient for any purpose. For observation of shocks of extreme violence, larger diameters in proportion to altitude should be chosen for all the cylinders.

The material of the cylinders is not important—cast-iron, stone, pottery, or other substances at hand—whose *arrisses* will not crumble away by being overthrown—may be used; but no material will be found more convenient than some hard heavy seasoned wood, of uniform substance, straight grain, and equable specific gravity, from which the cylinders can be formed in the lathe, and their bases brought perfectly square to the axes with facility.

Upon any horizontal and solid floor let two planks be placed, as in Fig. 6, with their directions in length respectively lying N. and S. and E. and W., each plank to be about 3 inches in thickness, and in width equal to the diameter of the largest cylinder, and its length such that the set of cylinders when placed upright and equidistant thereon shall have a space greater than the altitude, between each. Thus, if the cylinder of largest diameter have $b = 0{\cdot}5$ of a foot, the length of plank will, for a set of six, as in the fig., be about 12 feet. These base planks being *fixed* level and solid, the floor is to be levelled up with dry sand to their upper surfaces, and the two sets of cylinders adjusted to their places, one set running in an E. and W., the other in a N. and S. direction, so that in whatever direction the horizontal component of shock may move, the overthrown cylinders of one or the other set shall fall transversely to the lengths of the plank bases, and *lodging on the sand-bed, remain exactly in the position as to azimuth in which they were overthrown.* If now a shock of any horizontal velocity, capable of overthrowing some of the cylinders, but not all of them, arrive, it will throw down at once all the narrower ones, and up to a certain diameter of base. For example, suppose a N. and S. shock of such velocity as to overthrow W 6, W 5, and W 4, leaving W 3, W 2, and W 1 standing, then V will have been *greater* than the velocity due to the overthrow of W 4, and *less* than that due to the overthrow of W 3, and, within those limits, may be found from the preceding equation. The cylinders here overthrown, W 6, W 5, and W 4, will be found with their axes lying N. and S., at rest upon the sand-bed. The cylinders N 6, N 5, and N 4, will be also overthrown; but in this case they will fall in the line of their own plank basis, and *may* roll, and so give no indication as to direction of shock in azimuth. Hence the necessity for two sets of cylinders. One set, however, will be sufficient, if space enough be provided between the cylinders, and each be placed upon a cylindrical and separate basis of a diameter equal to its own, and in height equal to the depth of the sand-bed.

This form of instrument, then, is capable of giving approximate determinations of–

1. The velocity of the horizontal component of shock, neglecting the vertical component, which may be done where the angle of emergence is not great.

2. The surface direction in azimuth of the shock, or direction of horizontal component of the seismic wave.

3. Its absolute direction of primary movement, viz. *the direction of translation of the wave, which always coincides with the direction of molecular displacement of the wave itself in the first half of its complete phase*—*e.g.* if a shock in N.S. azimuth throw the cylinders to the southward, then the wave has traversed from S. to N.

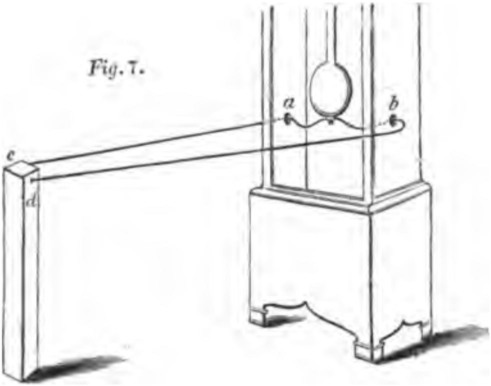
4. The exact time of the transit of the shock at the instrument may be also indicated, if either the narrowest cylinders, N. 6 and W. 6 (which by hypothesis must be *always* overthrown), be connected with a house clock in the way about to be described, so as to stop it at the moment of overthrow, or still better if a separate cylinder of even less stability, be appropriated to this purpose.

Three such sets of instruments at distant stations may of course be easily connected by galvanic wires, so as to give the transit time at each, accurately, and hence the transit rate.

Three or more distant observers, with chronometers, may of course *observe* this, but such observations can seldom be very numerous or extend over a large tract of country, and without automatic instruments shocks are almost certain to be missed at one or more stations; yet it is most desirable that a network of such observing points should be stretched over the shaken country. For this purpose common house-clocks, situated at several distant points, may be easily arranged, so that the pendulum shall be brought to rest and the clock stopped at the moment that the shock passes.

Fig. 7 shows part of the case and pendulum of a common clock. To fit it for this purpose bore two holes of a quarter of an inch diameter, one through either side of the clock-case, at *a b*, at the level of the lowest point of the pendulum-bob, and in the plane of its vibration; round off the edges of these holes, and grease them.

Fig. 7.



In the centre of a piece of fishing-line or stretched whip-cord make a loop and pass it round the screw or other lower projection of the pendulum-bob; pass the two free ends of the cord out, one through each of the holes in the sides of the clock-case; provide a squared log of heavy wood of about five or six inches thick each way, and from four to five feet in height; cut both ends off square, and stand the log upright on one end directly opposite the dial of the clock.

Measure off equal lengths of the cord at each side of the pendulum, and make fast their extremities to the two opposite sides of the upright log, *c d*, close to the top; bring the log backwards from the clock now, until the pendulum being at rest, both cords are drawn tight; and then advance it two or three inches towards the clock, so that the cords may be slacked down into a festoon or bend at each side of the pendulum, and *within the clock-case*, so that the pendulum may have room to swing freely; and *very slightly* wedge the cord to keep it so, through the holes in the clock-case, and from the outside; see that the log rests firmly and upright upon a firm floor; and now set the clock going. The length of the cords, or the distance of the log from the clock in relation to its height, must be such that if it fall *towards* the clock it shall bring the cords up tight before the upper part of the log touches the ground. It is now obvious that in whatever direction the log may fall, it will arrest the motion of the pendulum and stop the clock within less than a second of the true time of transit of the wave at the spot.

If the adjustments are similar for all the clocks this error will be constant for them all; and if the true time be noted at the principal station it can be got for the rest.

Clocks with seconds pendulums only, should be chosen for this use. They should be all set by one chronometer, and their errors afterwards taken.

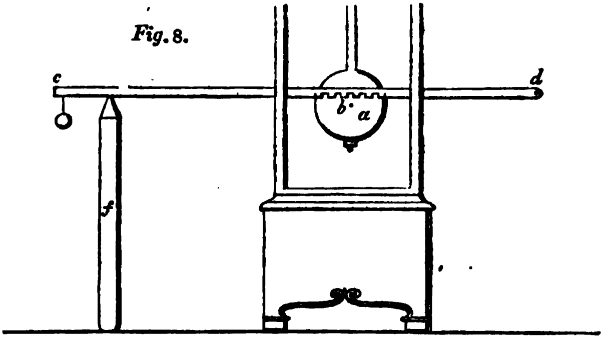
Where convenient, the pendulums should be all placed to swing north and south, or east and west; and in this case the sides of the logs will face the cardinal points, and the directions of their fall (where not entangled) be a rude index of that of the wave. It will be also desirable to place a tub of fluid to mark direction with each clock.

The positions chosen for the clocks must vary with circumstances, but they should, as far as possible, surround the principal station; their distances apart must be considerable, as the speed of the wave or shock is immense —probably five miles is the ordinary minimum, and thirty to fifty miles a convenient maximum distance. Such arrangements should be made as rapidly as possible after the first shock has given the expectation of others to succeed.

When practicable, the following method of fitting common clocks may be advantageously adopted. Let *a*, Fig. 8, be the pendulum-bob; fix a pin of stout wire into a hole in the centre of it, *b*, at right angles to the plane of vibration; cut two small mortices through the sides of the clock-case, so that a lath of deal or other light wood, of about an inch and a half wide by a quarter of an inch thick, may be passed through from *c* to *d*, just in front of the bob and clear of it.

Mark the length of the arc of vibration on the lower edge of the lath, and cut this length into nicks or teeth like a rack, of about three-eighths of an inch in depth and breadth each. Place the lower edge of the lath horizontally, and just above and clear of the pin *b*; secure the end of the lath *d* by a wire pin or stud, as a fixed point, so that the end *c* is free to move in an arc of a few inches up and down round *d* as a centre. Prepare a vertical log of wood *f*, of the size and form already described, but cut its upper end to a square pyramid, the flat surface at the top being reduced to about a quarter of an inch square; adjust the length and position of the log, so that it shall form a support for the end of the lath *c*, as in the figure.

Fig. 8.



It is obvious that the moment the log *f* is overthrown by a shock the lath will drop at the end *c* (which should be slightly weighted), and the teeth or rack nicks catching the pin *b* of the pendulum-bob will stop the clock; on examining which, the dial will show the time to a second when the shock took place, and the tooth in the rack will show at what part of the arc of vibration the pendulum was arrested, which will obviously give the time of the shock to a fraction of a second.

This method may be applied to any form of clock, and with any length of pendulum. Observation should be accurately made by a seconds watch, or still better, with a Breguet chronoscope, which readily reads to $\frac{1}{10}$ of a second, of the total duration of the shock in passing the observer's station; and the observer should endeavour to record the number of small, rapidly recurrent shocks, and their total duration at each epoch.

Returning now to observations to be made upon the earth-wave, indirectly or by its effects, consisting principally of—1. Observations on buildings and other objects, fissured, dislocated, or thrown down; 2. On bodies bent, projected, displaced, or inverted; 3. Bodies twisted on a vertical axis, with more or less displacement. Some of the most precious data are to be obtained, by the observation after the earthquake, of the fissures and dislocations of *buildings.* Choice should be made of buildings rectangular in plan, of tolerably good masonry, and but one story in height, such as churches, &c.; and as often as possible such should be chosen as have their principal walls running north and south and east and west. These may be advantageously described as *Cardinal buildings.* With a given force of shock, and in buildings of generally similar form, the extent of fissure depends chiefly upon the character and "bond" of the masonry. The direction of fissures, is nearly vertical when due to nearly horizontal shocks; but those of steep emergence produce highly-inclined fissures, often crossing each other. Cardinal buildings exposed to shocks, the horizontal component of which is either N.S. or E.W., are fissured chiefly near the quoins, and through the walls whose planes are in the line of shock. But irregularities in the mass of the walls, due to apertures, the brittleness of masonry, and slight deviations from cardinal direction in the shock itself, frequently produce subordinate fissures in the walls transverse to its line of movement, when these are not overthrown.

When the direction of shock is diagonal to the plan of the walls, a triangular mass is dislodged from the upper part of each of the adjacent walls, at the quoin *from which* the wave comes. With steep emergence such masses may be dislodged from both quoins at the same end of a rectangular building, which is that *towards which* the wave moves.

Heavy roofs and tiled or arched floors suffer most from shocks of steep emergence. Buildings situated near about vertically over the centre of disturbance present evidence of dislocation in every direction, *i. e.* by the vertical, or nearly vertical, emergence of the normal vibration, and by the nearly horizontal movements of the two transversal vibrations in orthogonal planes.

The observer must bear in mind that all these motions are due to the inertia of the bodies at the moment of the wave transit. The first tendency, therefore, of every body is to fall in a direction contrary to that of the wave's motion; but this is often perplexed by mutually-supporting bodies, as cross walls—by the direction of the wave being one in which a fall is impossible, as when passing very diagonally through a long line of wall—by disintegration from the first wave, so altering the conditions of the bodies (walls, towers, &c.), though short of producing a fall, as that the dislocation and fall produced by a succeeding one is not contrary, but in the same direction as the wave motion. When the shock emerges at a large angle to the horizon bodies are often projected, as stones out of or from the coping of walls: the size, weight, form, cement, sort of stone, distance thrown, and all other conditions of projection should then be carefully noticed. Isolated bodies, such as bells from belfries, balls or vases of stone, statues, &c., are often thrown from elevated points on buildings, and reach the ground after describing a trajectory path. The vertical height fallen through, and the horizontal distance thrown from the original position, with the form, dimensions, substance, weight, and mode of attachment of the body, being noted, afford elements for calculating the velocity of the wave transit if its direction of emergence be otherwise known, or *vice versâ.*

Fissured or overthrown walls of buildings usually give approximations to the horizontal azimuth of shock, but may or may not give any decided response as to the direction of transit, *e. g.* with a N.S. azimuth it may remain uncertain whether the transit was N. to S. or S. to N. Objects overthrown, such as images, altar candlesticks, pilaster slabs, pictures, that *can* fall only in one direction, may generally be found, such as will decide the question. Space will not permit of this part of the subject being treated systematically or fully. The observer should train his mind, by solving for himself various cases of the effects of shock on different sorts of buildings, &c., and he will see from the hints here given how much the value of his observations, in a recently shaken country, will depend upon the "nous" and adroitness with which he seizes upon the fit objects to afford him the best data. The note and sketch-books should be in perpetual use—no conditions essential for after calculation must be omitted—and the azimuths, directions, and emergence of the shock at every observed point marked upon the best maps as soon as possible. Azimuths must usually be taken with the prismatic compass, or pocket sextant, but should be plotted to the true meridian; and the magnetic variation should be determined at frequent intervals, especially in volcanic countries.

Bodies twisted on a vertical axis (such as the Calabrian obelisks, see Lyell, 'Geology') were formerly supposed to be due to a vorticose motion of the earth. This movement arises from the centre of gravity of the body lying to one side of a vertical plane in the line of shock, which passes through that point in the base on which the body rests, in which the whole adherence of the body to its support, by friction or cement, may be supposed to unite, and which may be called the *centre of adhesion*. (See Mallet, 'Dynamics of Earthquakes,' Trans. Royal Irish Acad., 1846.) The observer who fully masters these mechanical conditions of motion will see what elements he must collect, so that the motion impressed on bodies thus twisted may be used to calculate the velocity, &c., of the wave. All observations of this class, to be of scientific value, must comprise the materials, size, form, weight, sort of cement, base or foundation of the bodies disturbed, and measurements of the amount, &c., of disturbance, with any other special conditions which occur; and these will always be numerous, and demand the utmost alertness and scrutiny of the observer. The arc and azimuth of oscillation, with weight and length of chain or cord of suspended lamps set swinging by shock, often afford valuable information. The length to centre of oscillation is got by setting the lamp swinging, and noting the vibrations made in a minute, knowing the latitude; also iron crosses, or lamp irons *bent* by shock. The height, form, weight, exact section at the bend, and direction of deflection, to be noted.

Whatever difference in destructive effect may be due to formation or accident, it must be borne in mind that in every shock transmitted from a deep centre of impulse, and passing outwards in all directions in spherical shells, there will be a coseismal circle upon the earth's surface at some determinate horizontal distance from the central point vertically over the centre of impulse, in which the horizontal *upsetting* or *overturning* power will be a maximum, greater, cæteris paribus, than at any point within or without this circle: within, because there the direction of shock is more vertical, and therefore less calculated to overturn buildings; and without, because, though more horizontal, the power of the shock has become weakened by distance of transmission. This may be called the *Meizoseismal Circle* or *Zone*, having the radius Bc, fig. 1. It may be proved that the angle of emergence for this zone of maximum overthrow is constant, and makes with the horizon an angle equal to 54° 44′ 9″ nearly, assuming the energy of shock in the normal to vary as the inverse square of the distance from the origin. If therefore the centre of the circle, or point-plumb over the origin be given, or three points can be fixed by observation in the meizoseismal circle, the *depth of the origin below the earth's surface* can be calculated by the following rule:—

"Find the mean diameter of the meizoseismal circle. Then the depth of the origin or centre of impulse beneath the surface is equal to the diagonal of the square whose side is equal to the radius of that circle."

If the energy in the normal be assumed to vary simply as the distance from the origin inversely, then the constant angle of emergence for maximum overthrow is 45°, and the depth of centre of impulse is equal to the radius of the meizoseismal circle.

This gives us one method of approximating seismometrically to the depth below the surface of the volcanic "couche" beneath. The general horizontal direction of shock (radial from a point on the surface-plumb above the centre of impulse) is subject to great and often very perplexing and abrupt changes in azimuth and direction in very mountainous or shattered country, or even in perfect planes of deep alluvium (like the basin of the Ganges) resting upon a highly uneven skeleton of rock, or where the formations vary suddenly and much, or are very discontinuous. The change often amounts in direction to total inversion, and in azimuth to 90°.

Great perturbation of direction is also produced by the abutting of one mountain chain upon another, which usually alters the apparent angle of emergence also. The methods of disentangling these larger and complex phenomena exceed the limits here imposed. (See 4th Report Brit. Ass. Trans., 1857-58.)

Amongst doubtful phenomena on record are *inversions* of bodies, such as parts of pavements turned upside down, &c.: such cases, or any strange and unaccounted for, phenomena, deserve special attention. (See 1st Report, 'Facts of Earthquakes,' section 6, Secondary Effects; 'Cosmos,' vol. iv., Sabine's Translation.)

In traversing an extensive city, or thickly built-over country, to observe the shattered buildings—having first ascertained generally the line of motion of the wave—the observer should remark where its direction of motion has appeared to change as it passed along, and note all the conditions that seem to have there affected it. He should also obtain decisive evidence of its actual transit, for sometimes the wave seems to emerge all but simultaneously over a vast tract of country, where the origin is deep-seated, and nearly vertically below. Changes in the rate of transit horizontally, or in the energy of the wave, should be noted by its effects on *similar* objects at *distant* spots. These changes may be expected, at the lines of junction of different rocks or other formations. Evidence should also, if possible, be got of any breaking up of the primary wave into secondary waves, as of several shocks being felt where only one has occurred further back.

All evidence should, as far as possible, be *circumstantial.* Nature rightly questioned never lies; men are prone to exaggerate, at least where novel and startling events are in question.

Various *local conditions* must be recorded:—the great features of the geological formations of the region, not only the successive underlying rocks, with the general directions of bedding, lamination, joints, &c.; but *the topographical character* of surface, the directions and altitudes of the chief mountain ranges and of the main river courses, the depth and description of its loose materials, their variations and extent, and the same for the surrounding districts, from whence and towards which, the earth-wave travels especially. The deeper a knowledge can be got by exposed sections, &c., of the rocks of the shaken district the better, the proximity or otherwise to volcanic vents, active or passive, the lithological character of material of the country shaken, whether broken, solid, or fissured; if the latter, their general directions, dip, &c., whether dry or flooded, and the effects on the transit of the wave, of changes in any or all of these conditions. Places least and most affected by the shock, and whether there be some free from any, and their local conditions, to be particularly noted.

Referring now to *secondary phenomena*, or effects resulting from the transit of the earth-wave (other than merely measures of it), we should observe falls of rock, or land-slips, to which most of the conditions of shattered buildings apply. Land-slips change their initial directions frequently, in consequence of moving over curved or twisted surfaces of rock: thus the previously straight furrows of a field may be found twisted after an earthquake. Scratches or furrows engraven on rocky surfaces by such land-slips should be looked for.

Sometimes great sea-waves are produced by the fall into the sea of rock or land-slips, which need to be carefully distinguished from the true great sea-wave produced by an original impulse of the sea-bottom. Land-slips often dam rivers, fill up lakes; and various changes of surface again produce basins for new lakes, to be filled by the changed river-courses. The circumstances, as far as possible, should be accurately observed, and the causation of the events unwound, and all such phenomena cautiously separated from actual ejections of water (temperature to be ascertained), which are *said* sometimes to have happened on an immense scale. (Humboldt, Personal Narrative; 'Cosmos,' vol. iv.)

Fissures containing water often spout it up, at the moment of shock. Wells alter their water-level, and sometimes the nature of their contents; springs become altered in the volume of water they deliver. The directions of the fissures, and the relations of such directions to that of the shock, should be ascertained, and any changes in the temperature of wells noted. Ejections from holes or fissures of strange liquid or solid matters, sometimes of dry ashes or dust, are recorded, and occasionally fiery eructations or smoke *are said* to have occurred, especially near volcanic centres, and blasts of steam-vapours, or gases, whose chemical characters should be in all the above cases observed, as far as possible. The dust of overthrown buildings, or that produced by the rending of rocky or other masses, must not be confounded with these. Fissures, sometimes of profound depth, open and remain so, or close again: their directions, dimensions, time and order of production, and closing up, and the formations in which they occur, to be noted; bodies engulfed to be detailed, as future organic remains. Fissures in solid rock arise either from the effects of inertia or from the range of molecular displacement of the passing wave, exceeding the elastic limit of the materials disturbed; but fissures in earth or other discontinuous and very imperfectly elastic masses seem due only to the secondary effects of the shock, producing land-slips, subsidations, &c. (see 'First Report on Facts of Earthquakes,' sec. 6, Secondary Effects). *Permanent elevations and depressions* of the land usually accompany earthquakes, and are of much importance to science, but, as already remarked, must be viewed as clearly distinct from the earthquake itself. Such elevations or depressions have a common cause with the earthquake; both are due to the volcanic efforts beneath, but are not the less absolutely distinct phænomena, to confound which, is to lose sight of all true science in both. The observation of these should never be neglected, though rather belonging to geology proper. The half-tide level must in all cases be taken as the datum-plane for all questions of level, and opportunities diligently sought for along beaches, quays, wharfs, or inland along mill-streams or irrigating channels, &c., where alterations of level may be trustworthily evidenced by changes of depth or run of water. Occasionally local, but widely-extended, permanent elevations or depressions accompany earthquakes, which seem to result from lateral compression, and not from direct elevatory forces. These should be distinguished from the preceding.

Rivers are stated to have sometimes run dry during earthquakes, and again begun to flow after the shock. This is presumed to arise either from the transit of an earth-wave along their courses up stream, thus damming off their sources, or from sudden elevation of the land, and as sudden depression. Where well observed, however, it has nearly always been found due to sudden damming up by falls of rock or earth at narrow points of their courses—the débris being soon afterwards swept away.

Observations of the *forced sea-wave*, whether produced by the earth-wave going out to sea or coming in from it, will be nearly the same. It is desirable to find its height above the surface of repose referred to half-tide level, and its length or amplitude; but from the extreme rapidity of its production and cessation, or conversion into small oscillatory waves lapping on the beach, and its generally small altitude, observations are extremely difficult—they are only possible when the surface of the sea is perfectly calm, and then must be left to the skill of the observer in taking advantage of local circumstances, and of evidence as to the visible circumstances of this wave, which occurs at the instant the shock is felt.

Observations of the *waves of sound* through the earth, the sea or fresh water, and the air, are indicated pretty fully by the description of these waves already given. The sound-wave through the earth travels probably at the same rate as the shock, or earth-wave; it is, in fact, *the shock* (*or its fractures*) *heard*. Notice if any and what sound is heard before, along with, or after the shock is felt. An observer, putting one ear in close contact with the earth, and closing the other, will hear the sound-wave through the earth separate from that through the air, and thus hear sounds otherwise inaudible. So also an observer immersed in the sea will hear the sound-wave through it, sometimes without any complication of that through the earth.

An exact description of the character and loudness of the sounds heard, and the places in an extensive district where each was heard loudest and faintest, with the nature of the rock formations at these spots, should be noted. The duration of the sound from first to last, through either medium, accompanying each shock, is important. Circumstances of a character analogous to those upon which the rumbling and reverberation of thunder depend, may affect these sounds transmitted through the earth and thence to the air.

Observations on the *great sea-wave* should embrace, for each wave, its height, its amplitude or length, its velocity and direction of translation. The height to be taken above the plane of repose of the fluid, and referred to half-tide level. These waves, when on their grandest scale, defy any methods of direct admeasurement. But observations of their results, such as the height to which they have reached on mural faces of rock, or on such buildings, &c., as may have withstood them, or eye-sight observations made at the moment of transit of the crest of the wave, cutting distant objects, should not be omitted; when of a manageable size the height of the crest may be pretty closely obtained by the traces on wharfs, buildings, &c., or on posts or piles driven into the littoral bottom; it may be taken from any convenient fixed points of level, and all ultimately referred to half-tide as the datum for all earthquake observations as to level.

The sextant may be occasionally used to get the elevation of the crest of the passing wave, several observers making a simultaneous observation of an expected wave. The velocity of the wave may be got by noticing from a suitable position, by a seconds watch, the time of its transit inwards between two distant points having water between them whose depth is or may be known. Islands off the land are advantageous posts for this purpose. Where tide-gauges can be established, they afford the best means of recording all the conditions of these waves when of a manageable height. The state of the tide at the time of their occurrence, and the general nature of the local establishment, with the in and off shore currents, should be ascertained.

The length of the wave (while entire) should be sought for by a similar method; a knowledge of its length and of the depth of water infers its height. There are two indirect methods by which the dimensions of the great sea-wave may be pretty accurately determined:—1st. The distance to which solid bodies before at rest are translated by the passage of the wave over them is about equal to its length or amplitude; so that when we can obtain evidence of the distance to which a large loose rock, for example, whose precise position was before known, has been carried, we approximate to one dimension of the wave. 2ndly. The depth of water at the point where the wave is first observed to break, when capable of being accurately found, gives the height of the wave, which is here equal to the depth of the soundings. This breaking point and depth should always be anxiously tried for. Besides the dimensions of the wave, observations should be made, on the interval of time, after the great earth-wave, or shock, and before the great sea-wave comes in, reckoning from the *commencement* of the shock. When more than one great sea-wave comes in, the precise number of successive waves, and the intervals in time of their recurrence, should be noted; also what are their relative dimensions; what changes are observable in the directions whence they arrive at the same point of coast, and what are the several in-coming directions at various points along a great stretch of coast (the latter must be had usually from collected testimony); what reflux from the beach before or after the coming in of the wave; after the wave has come in and broken, what oscillatory waves are produced, their character and dimensions; whether the level of the surface of the sea is, in repose, the same before and after the subsidence of the great sea-wave and its secondary or oscillatory waves; whether any subsequent irregularity of tide occurs after the shock or great sea-waves, or any permanent change of establishment, should be ascertained.

As accurate a section as possible of the form of the littoral bottom, beach, offing, and out to deep water, should be got by soundings in the line of the coming in of the wave, and laid down on paper. It should be noticed whether the great wave comes in of muddy or discoloured water, or clear and like the sea it traversed; and, where possible, a cruise should be made out to sea in the direction whence the waves came, to look for pumice, dead fish, volcanic ashes, or other indications of the distant origin or centre of disturbance. The cotidal lines of the great waves should be laid down in direction upon a map of the coast.

The secondary effects of the great sea-wave most worthy of remark are the materials, if any, carried in from deep sea, such as loose mineral matter, new animal or vegetable forms, or the substances swept from off the land, and sunk in the depths of the sea. As the range of transferring power of a great sea-wave (wave of translation) is only equal to the length of the wave itself, but little matter will be carried inland from the sea bottom, unless where the depth is great close to shore.

If fish or testacea are thrown inland into fresh water, the effects on them should be noticed. Lastly, the effects of the passage of the wave over the land and all that stands upon it are to be observed. In recording the transporting power of the wave (*i. e.* its absolute transferring power, without reference to distance), the size, form, specific gravity, and lithological character of rocks or boulders moved, the distance moved, and height lifted are to be given; the base on which moved, and if rock, the scratches or furrows produced; the mode of motion, and if swept or rolled along; the obstacles overcome in their progress. Where gravel or loose materials are moved, there should be given an estimate of the mass moved, and to what distance; the character, external and internal, of its deposition; the mutual relations, or sorting, of its fine and coarse parts. The effects on buildings variously exposed; on vertical and sloping sea-walls; on steep faces of cliffs, and on the caverns excavated in them. The *denuding* effects of the wave in sweeping off sand, gravel, trees, animals, &c. The disruption and lifting of masses and abrasion of stratified rocks, especially of nearly level and nearly vertical beds. Effects of vertical sea-walls or cliffs in the reflection or extinction of the wave.

Specimens should be taken of the rock of which very remarkable boulders or architectural fragments moved by the wave consist; of any new or strange matters cast up, or gases or vapours evolved from the sea, or ejected from fissures, cavities, wells, &c., on land; of mineralized or suddenly fouled water found in fissures or wells. Of these, where possible, immediate chemical qualitative examination should be made.

Such specimens in particular should be brought home of the rocks or other mineral masses through which the speed of transit of the earth-wave has been carefully observed, as will enable the mean *modulus of elasticity of the mass* to be determined. Where this is rock, three specimens should be taken of maximum, minimum, and average hardness, density, and compactness, as representatives of the whole, noticing especially in stratified rock the depth from surface of ground and from top of the formation at which taken: each specimen to be of a size enabling a block to be sawn out of it of at least three feet in length by four inches square. Where convenient, this operation may be done on the spot. An iron wire stretched like a bowstring, with some sharp sand and water, makes an excellent stone saw; still better where continuous motion can be given by a band to the wire wheel and winch handle. Where the district is a deep detrital or alluvial one, the depth and characters of the loose materials should be carefully observed, and illustrative specimens, as far as possible, brought home. It is in the highest degree important that the degree of shatteryness or compactness of the rock formations, the nature, directions, closeness, or openness, and contiguity of the fissures be remarked, as these conditions of comparative discontinuity most materially affect the transit period of the shock in every formation.

Collateral conditions to be observed are—barometer before, during, and after the earthquake; thermometer and rain-gauge; hygrometer and electrical state of the air during the phenomena; magnetometrical observations to be made where these are practicable; all unusual meteorological appearances to be noted, and all changes or perturbations of climate or season observable for a year before and after the shock, are desirable to be ascertained. Also whether epidemic or other diseases follow and have a distinct connection of cause and effect with the earthquake, as by change of season, failure of crop or food, injury to arterial drainage, the presence of fogs or exhalations, or like events.

The effects of the shock itself on man and the lower animals to be noticed. Nausea is undoubtedly a frequent effect upon human beings at the instant of shock; but the nature of its production is uninvestigated. Is it due to nervous perturbation, or to the movement, as in the case of sea-sickness? Some animals appear to predict the shock before men are conscious of its approach. Birds are often killed by being thrown off their roosts while asleep at night. Flat fish on the sea bottom are often killed by the direct blow of the steeply emergent wave. All such modes of death should be noted. Active volcanic phenomena occurring before, during, or after the earthquake, in adjacent or distant regions, will of course be recorded.

Records or trustworthy traditions are to be sought for, in new or little explored volcanic countries or those neighbouring to them, as to the state of activity or repose of these vents for a long period prior to and during the earthquake; also as to their state before and during any previous earthquakes—all remarkable facts as to which should be collected. Where meteorological or tidal tables exist, they should be transcribed for the times correlative to the above records. The opinions of old observers as to changes of climate or season; the occurrence of pestilences, failure of crops, &c., in relation to earthquakes, while they must be received with caution, should not be disregarded.

Any changes of permanent level of sea and land that accompanied former earthquakes that are on record should be obtained, with their particulars; whether the same points have been affected in successive earthquakes, and by successive upheavals; whether the same or different volcanoes were in action during successive earthquakes; and whether the area of disturbance in habitual earthquake regions seems to enlarge in successive shocks. (Humboldt, 'Cosmos.')

Upon maps of the country in which the shock was felt, coseismal and meizoseismal curves may be finally laid down, upon which also the cotidal lines of the great sea-waves on a long coast-line may be marked. Maps of fissures formed in relation to the coseismal lines, and generally sketches of all visible remarkable effects of the earthquake on natural or artificial objects, should be made. Photography affords precious facilities for preserving the appearances of shattered buildings and the relations or alterations of natural features, &c. The effects of earthquakes on the lives of men and animals; statistics of mortality; modes of entombment by the convulsion, as bearing on future organic remains; burying of objects of human art,—are all worthy of notice.

It sometimes happens that a shock of earthquake is felt at sea, at great distances from land, and over profound depths; a sudden blow is felt, as if the ship had struck a rock. (See 'Comptes Rendus,' vol. vi., pp. 302 and 512, 1853.)

The earth-wave coming from an origin probably in most cases nearly vertically beneath, is here transferred to the ocean, through which it passes upwards as an elastic wave, with the same speed as the sound-wave through the sea. When such an event occurs in a smooth sea, and circumstances are favourable, we should look out for and note the direction of the passage almost immediately in form of a single, low swell, of the great sea-wave, which may be formed directly over the origin, at no very great distance off. Immediate attention should be given to the particulars of any objects that may have been displaced on board. Compasses are thrown out of the gimbals, shot dislodged from their seats round the hatchway coamings, or other places; a mast has even been unstepped. The relation observed between the extent of lateral and of vertical displacement will give some notion of the deviation of the line of shock from the vertical, and of its slope in azimuth. This found, a cruise about, may be made in search of pumice, discoloration, or other indications upon the surface of the sea, &c., of the origin under the sea bottom. Where the depth of water is great, it is improbable that any indications of the convulsion below will reach the surface. Efforts, however, should be made to reach the bottom with the armed lead line and to obtain two lines of soundings at equal intervals for some miles, running both in latitude and longitude, and to bring up specimens of the bottom at each throw of the line. The origin may be found to be a newly-emerging volcano, an object always of great interest; the observation when in deep water is capable of adding much to our knowledge of Chemical and Physical Geology.

Perhaps no branch of Terrestrial Physics will so richly repay to the observer who is so fortunate as to be able to reach the greater seats of volcanic and seismic action of our globe, the labour that will be necessary beforehand, to enable him effectually to grasp his subject, as seismology; but observations undertaken without such preliminary knowledge will for the most part be valueless.

Besides the study of the several works already mentioned in the text, Lyell's 'Geology,' *passim*, should be studied, and a few of the best narratives of earthquakes perused. Such are Hamilton's and Dolomieu's 'Accounts of the Great Calabrian Earthquake' (neglecting their theoretic views); Humboldt's, Admiral FitzRoy's, and C. Darwin's Accounts of the South American, and Sir Stamford Raffles' Account of those of Java; with several others.

ARTICLE XIV.

FOURTH DIVISION, SECTION 4.

ZOOLOGY.

BY RICHARD OWEN, ESQ.

Instructions for Collecting and Preserving Animals.

As water is the element in which the greater number of the classes of animals exist, and as the sea is the scene of such existence and the field of research which will be most commonly presented to those for whom the following instructions for collecting and preserving animals have been drawn up, they will commence with the marine species and the lowest forms of animal life.

ALGÆ, SPONGES, CORALLINES, and CORALS.

The line of demarcation between the vegetable and animal kingdoms is so obscurely marked in the lowly organized marine species, and the modes of collecting and preserving these are so similar, that the kindred groups above-named are associated together as the subjects of the following remarks.

Algæ, commonly called seaweeds, may be divided, for the convenience of the collector, into three kinds, according to their colour:—

1. Olive-coloured (*Fuci*); generally of large size and leathery texture, rarely gelatinous; usually laminate or leafy, rarely filamentous or thready.

2. Red-coloured (*Florideæ*); firm, fleshy, or gelatinous; usually filamentous, sometimes membranaceous.

3. Green (*Chlorosperms*); membranaceous or filamentous; rarely horny.

Sponges are bodies usually adherent in irregular or amorphous masses, rarely in the form of hollow reticulate cones; they are composed of a soft, jelly-like tissue, supported by siliceous or calcareous spiculæ, or by horny filaments. They are divided accordingly into horny or "keratose," flinty or "siliceous," and limey or "calcareous" sponges. Their soft organic substance is commonly diffluent, and drops from the firmer basis when removed from the water, or it is easily washed away. It exhibits no sign of sensibility; no contraction or retraction when touched or otherwise stimulated. The evidence of life is afforded by the flow of currents of water through canals, entering by pores and escaping by larger orifices: an appearance of animal life is given to both algæ and sponges by the locomotion of the sporules or gemmules.

Corallines are plants coated with a calcareous covering, either red or green when fresh, becoming white and brittle on exposure to the air.

Corals, though called "zoophytes," are true animals; the currents which permeate them enter by "mouths," always provided with a crown of feelers or seizers, called tentacles, and communicating with digestive sacs or "stomachs," into which the pores of the nutrient canals open. The tentaculated mouths are called "polypes." Their fleshy tissue, as well as that which connects them together into an organic whole when the coral is compound or has more than one mouth, is "sensitive," or retracts and shrinks when touched. For the purposes of the collector corals may be divided into the "fleshy" (*Polypi carnosi*), in which the flesh has no firm supporting part; the "horny" or "flexible," usually having this supporting substance as an external tube; and the "calcareous," in which the supporting substance, composed of carbonate of lime, is usually covered by the animal matter or flesh, forming an internal skeleton, usually of one piece, rarely jointed.

The above-defined classes of organized beings, which all present, more or less, the "habit" or outward form of plants, are found from the extreme of high-water mark to the depth of from 50 to 100 fathoms. Living algæ rarely descend below 50 fathoms, but corals of the genera *Lepralia*, *Retepora*, and *Hornera* have been dredged up from 270 fathoms, and fragments of dead coral from 400 fathoms.* Specimens within the reach of the tide are to be collected at low water, especially of spring tides: the most interesting species occur at the verge of low-water mark. Those that dwell at greater depths must be sought by dredging, or by dragging after a boat an iron cross furnished with numerous strong hooks. One or more strong glass bottles with wide mouths, or a hand-basket lined with japanned tin, should be provided for the purpose of bringing on board the smaller and more delicate species in sea-water, and they should be kept in it, the "*Florideæ*" more especially, until they can be arranged for drying, or other modes of permanent preservation can be attended to.

In collecting algæ, corallines, or the branched, horny, or calcareous corals, care should be taken to bring the *entire specimen* with its *base or root*. With respect to the coarser algæ, it is merely requisite, for the purpose of transmission, to spread the specimens immediately on being brought fresh from the sea, without previous washing, in an airy situation to dry, but not to expose them to too powerful a sun: if turned over a few times they will dry very rapidly. When thoroughly dried they may be packed loosely in paper bags or boxes, and will require only to be re-moistened and properly pressed, in order to make cabinet specimens. For the purpose of transmission it is better *not* to wash the specimens in fresh-water previous to drying, as the salt they contain tends both to preserve them and to keep them pliable, and more ready to imbibe water on re-immersion. With respect to the delicate algæ:—"The collector should have two or three flat dishes, one of which is to be filled with salt water and two with fresh; in the first of these the specimens are to be rinsed and pruned, to get rid of any dirt or parasites, or other extraneous matter; they are then to be floated in one of the dishes of fresh water for a few minutes, care being taken not to leave them too long in this medium, and then one by one removed to the third dish, and a piece of white paper, of the size suited to that of each specimen, is to be introduced underneath it. The paper is to be carefully brought to the surface of the water, the specimen remaining displayed upon it, with the help of a pair of forceps or a porcupine's quill, or any fine-pointed instrument; and it is then to be gently drawn out of the water, keeping the specimen displayed. These wet papers, with their specimens, are then placed between sheets of soft soaking-paper, and put under pressure, and in most cases the specimen adheres in drying to the paper on which it is laid out. Care must be taken to prevent the blotting-paper sticking to the specimens and destroying them. Frequent changes of drying-paper (once in six hours), and cotton rags laid over the specimens, are the best preservatives. The collector should have at hand four or five dozen pieces of unglazed thin calico (such as sells for 2*d.* or 3*d.* per yard), each piece about eighteen inches long and twelve inches wide, one of which, with two or three sheets of paper, should be laid over every sheet of specimens as it is put in the press. These cloths are only required in the first two or three changes of drying-papers; for, once the specimen has begun to dry, it will adhere to the paper on which it has been floated in preference to the blotting-paper laid over it." *

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* Captain Sir James C. Ross, 'Antarctic Voyage,' Appendix, No. IV.

For dried specimens of corallines, corals, and sponges, it is advisable to soak the specimen for a time in fresh water before drying. They may then be packed among the rough-dried seaweeds in boxes; but the more delicate specimens should be placed in separate chip-boxes with cotton.

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* Dr. Harvey, in Mr. Ball's 'Report on the Dublin University Museum,' p. 3.

With regard to corals, &c., it must be remembered that dried specimens are but the skeletons of those animals, and that only the "horny" and "calcareous" species can be so preserved. The "fleshy" kinds, commonly known as "polypes," "sea-anemones," or "animal-flowers," must be preserved entire in alcohol, glycerine, or saline-solution, and of the latter the following (No. I. of Goadby's recipes) has been found successful:—

SOLUTION No. I.

Bay salt	4 oz.
Alum	2 oz.
Corrosive sublimate	2 grains.
Rain-water	1 quart.

In order to preserve the specimens expanded they should be removed and placed alive in a dish of sea-water; and when they have protruded and expanded their tentacles, the solution should be slowly and quietly added to the sea-water, when the animal may be killed and fixed in its expanded state. So prepared, the specimens should be transferred to a bottle of fresh solution.

In like manner the minute polypes of the flexible or horny corals may be preserved protruded from their cells and expanded. If a small piece of corrosive sublimate is put into the vessel of sea-water containing such living polypes, it will kill or paralyse them when protruded, as it slowly dissolves; but they must be removed as soon as they have lost their power of retraction, otherwise their tissue is rendered fragile or is decomposed. The polypes or animal part of the calcareous kinds, called "madrepores," "millepores," "fungiæ," "red coral," "gorgoniæ," &c., require for their preservation, in connexion with their supporting basis, the following solution (No. II.):—

SOLUTION No. II.

Bay salt	½ lb.
Arsenious acid, or white oxide of arsenic	20 grains.
Corrosive sublimate	2 grains.
Boiling rain-water	1 quart.

All the polypes concerned in the formation of coral-reefs, atolls, or coral-islands, may be preserved in the above solution, provided they be killed by its gradual application as above described, and be afterwards transferred into fresh solution. With regard to the structure and formation and mode of observation of coral islands and reefs, the work by Charles Darwin, Esq., *On the Structure and Distribution of Coral Reefs* (8vo., 1842), should be consulted.* Never fail to ascertain, if possible, to what depth below the surface of the sea the corals descend, and on what basis they rest; and for particular instructions with reference to coral reefs, see Mr. Darwin's remarks under the head of 'Geology.'

INFUSORIAL ANIMALCULES (*Polygastria, Polythalamia, Phytolitharia*).

Some idea of the value and importance of attending to the collection of these microscopical organized beings may be had by reference to Ehrenberg's Observations forming Appendix No. V. of Captain Sir James C. Ross's 'Antarctic Voyage,' vol. i. p. 339; a better idea by the perusal of Ehrenberg's numerous communications to scientific journals, some of which have been translated in Taylor's 'Annals of Science;' and the best idea by the study of Ehrenberg's great work, 'Entwickelung, Lebensdauer und Struktur der Magenthiere und Räderthiere,' &c., fol., 1832. The important relations of these minutest forms of animal life to great questions in geology, to the alteration of coast-lines, and to the phenomena of oceanic luminosity, make it indispensable to include them in directions for collecting facts in natural history.

Whenever the surface of the sea presents a difference of colour and density, in the form of pellicles, streaks, or shining oil-like spots, lift up portions by dipping in thin plates of mica or stout paper, and raising them horizontally: dry these and preserve them in a book, noting the latitude and longitude, the time of day, and the temperature of the sea. The animalcules remain attached to the pieces of paper or mica employed in their capture, and may be determined by subsequent microscopical observation.

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* See also, on this subject, Lieut. Nelson's paper 'On the Geology of the Bermudas;' Geological Transactions, 2nd Series, vol. v. pp. 103-123.

Where the sea seems pure and colourless a bucketful may be raised and strained through fine linen; by repeating this act a portion will commonly remain on the filter, which is then generally rich in invisible animalcules, and should be preserved in small glass bottles or tubes, with a bubble of air between the cork or stopper and the water. Any visible gelatinous acalephæ should be removed and placed in spirit of wine, glycerine, or the solution No. I. Specimens of sea-water thus saturated with animalcules should be prepared at each degree of latitude and longitude traversed on the voyage, by which means the geographical distribution of these minute organisms may be ascertained, when the species so collected are determined, after the voyage, by microscopic observation.

Small bottles or tubes of the water of each mineral spring or hot-spring should be preserved for the same purpose. In a deposit from melted pancake-ice from the Barrier, in 78° 10′ S. lat., 162° W. long., brought home in Ross's Antarctic voyage, Ehrenberg detected of siliceous-shelled Polygastria fifty-one species, including four new genera; siliceous Phytolitharia twenty-four species; and of calcareous-shelled Polythalamia four species. Small packets of the sand of each coast that may be visited, and of the sand or mud brought up with the anchor or the sounding-line, should be preserved; the localities, or latitude and longitude, being precisely noted in each case.

ACALEPHÆ (*Sea-blubber or Medusæ, Portuguese Men-of-war, Jelly-fish, and other floating marine gelatinous animals*).

The brilliant but evanescent hues of many of this class of animals can only be preserved by coloured drawings executed at the time of capture. The solution No. I. will suffice for the preservation of the animals themselves, provided it be changed after they have remained in it about twenty-four hours, for most of the gelatinous animals, especially the medusæ, contain a great quantity of fluid, which, mixing with the preserving liquid, dilutes it, and renders it unfit for long-continued preservation. The best preserved specimens of these delicate animals are those that have been placed, immediately after capture, in the solution No. I. diluted with an additional pint of rain-water, and which have been afterwards transferred to fresh solution of the proper strength. Glass-stoppered bottles with wide mouths are the best adapted for the larger Acalephæ.

ECHINODERMS (*Star-fish* [*Asterias*], *Sea-urchins* [*Echinidæ*], *Trepang or Sea-cucumbers* [*Holothuriæ*]).

For the preservation of the entire animal with the soft parts of a star-fish (*Asterias*), or a sea-urchin (*Echinus*), glycerine or the arsenical solution (No. II.) is preferable: the softer trepangs (*Holothuriæ*) may be preserved in solutions Nos. I. or II. It should be gradually added to the vessel of water in which the living specimen is at rest, in order to kill it, with the soft appendages protruded or elongated. This is particularly requisite in the case of the *Holothuriæ*, which, if plunged suddenly in solution, are apt to squeeze out and rupture their viscera. With regard, however, to long and slender star-fishes (*Ophiuræ*), sometimes called "brittle stars," from their habit of breaking themselves into pieces when captured, these should be instantly plunged into a vessel of glycerine, or a large basin of cold fresh water, when they die in a state of expansion, and too quickly for the acts of contraction by which the rays are broken off. After lying for an hour or so in the fresh water they may be transferred to the solution: if preserved dry they should be dipped for a moment in boiling water, then dried in the sun or in a current of air, and packed in paper. When the specimens have soaked in solution one or two days, according to the temperature, they should be removed into fresh solution. The Echini should be sewed up each in a separate bag of muslin, and not be crowded so as to press upon each other in the same bottle. The star-fish and sea-urchins that are preserved dry should be emptied of their viscera or soft contents by the mouth or larger (lower) aperture, and should then be soaked in fresh water, changed two or three times, for so many hours, or until the saline particles of their native element have been extracted, before they are dried. The Echini should be wrapped up in cotton and sewed up, each in its separate bag, in order to preserve the spines, which may become detached in the course of a voyage, and are apt to become so if the precaution of soaking away the saline particles be not previously taken. All Echini and star-fish should be examined for small shells (*Stylifer* of Broderip, for example), which nestle in and among the rays and at the roots of the spines, and for other parasites.

Recent Pentacrini (Lily-stars), especially their bases, will be valuable acquisitions. They may be dredged up of large size in tropical seas, as those of Guadaloupe, for example.

ENTOZOA (*intestinal worms and other internal parasites*).

These are to be preserved either in solution No. I., in glycerine, or in colourless proof-spirit. This class of animals has been commonly neglected by collectors. Every animal that is opened and dissected, especially fishes, may present rare or undescribed species of Entozoa. The eyes of fishes are often the seat of such : the noses of sharks are frequently infested by them. They may be found not only in the alimentary canal, but in the tissues of most of the organs. When the parasite is adherent, the part to which it adheres should be removed with it, care being taken to secure the whole mouth or proboscis of the parasite. When it is encysted in an organ, the cyst is to be removed entire with the surrounding tissue of the organ. Portions of muscle or other tissue which appear speckled with minute white spots should be preserved, as these may be occasioned by the cysts of *Trichinæ*, or allied microscopic Entozoa. The number attached to the specimen should correspond with that in the list having reference to the animal and part or organ infested by the parasite.

EPIZOA (*Lerneæ or Fish-lice, and other external parasites*); ANNELIDES (*Leeches, Worms, Nereids, or Sea-centipedes, Tube-worms, &c.*).

The exterior surface, the mouth, and the gills of all fishes should be examined for parasitic animals, some of which exhibit the most extraordinary forms and combinations of structure, as, *e. g.*, the *Diplozoon* of NORDMANN, a genus of Entozoa, from the gills of the bream. When the parasites adhere firmly to the part they should be cut out with the adhering organ entire, which sometimes penetrates to a great depth in the flesh. The exterior surface of porpoises, grampuses, and the larger species of the whale tribe should be scrutinized for adherent parasitic animals. Rare kinds of leeches may be found on fishes, as, for example, the *Branchellion* of the Torpedo. A species of leech with external tufted gills, *Hirudo branchiata*, has been detected on a marine tortoise or turtle in the Pacific, the anatomical examination of which is especially recommended by Cuvier. Leeches and all the various kinds of sea-worms comprehended under the class name "Annelides," and including the Nereids, or sea-centipedes, usually found amongst sea-weed or under stones, sometimes attaining the length of twelve feet;* and the tube-worms usually crowned with brilliant coloured tentacles, may be preserved in the solution No. I. or in colourless spirit. Those, however, as the *Serpulidæ*, that form calcareous tubes, should be preserved in the solution No. II. In all cases it is desirable that the specimens should be allowed to die gradually in the water they inhabit, when they commonly display their natural external form and appendages in a relaxed state; they should then be immediately put into the solution or spirit to prevent putrefaction, which otherwise takes place rapidly.

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* See the specimen, from Bermuda, of *Leodice gigantea*, No. 253 *a*, Museum, College of Surgeons, London.

CIRRIPEDIA (*Barnacles and Acorn-shells or Crown-shells*).

The Barnacles or pedunculated Cirripeds, with soft stalks, should be preserved in the solution No. II., in glycerine, or in spirit; they are commonly attached to floating timber, and the smaller species to seaweed, shells, &c. The sessile kinds (acorn-shells, &c.), which encrust the coast-rocks all over the world, and are found parasitic on turtles, whales, &c., should likewise be preserved in spirit or solution No. II., as the included animal is necessary in some genera for the recognition of the species. The colours of the pedunculated kinds should be noted whilst fresh. If the sessile kinds are preserved dry, the included animal ought never to be taken out. In removing all the kinds from their points of attachment, care must be taken that, in some specimens at least, the base, which is either membranous or calcareous, be preserved. It is particularly desirable that some young as well as large specimens should be collected. In the tropical seas certain corals and shells contain embedded in them singular forms of cirripeds, which, presenting externally little more than a simple aperture, are easily overlooked; such kinds had better be preserved in the coral. Others live embedded in sponges; two genera live on whale's skin (*Coronula* and *Tubicinella*), the development of which needs to be studied by specimens of the ova and young; another less known genus (*Chelonobia*) lives partly embedded in the skin of turtles; a third attaches itself to the manatee or sea-cow; and some small and interesting species of barnacle are parasitic on sea-snakes. Lobsters, crabs, bivalve and other shells, as well as floating pieces of wood, or even net-corks, become the habitat of animals of the class *Cirripedia*. It should always be noted to what animals these parasitic cirripedes are attached, as well as any circumstances that may determine the period during which they have remained attached.

CRUSTACEA (*Shrimps, Sea-mantises, Cray-fish, Lobsters, Crabs, and King-crabs*).

All the animals of this class are most usefully preserved in spirit or solution. If they be covered by a soft, flexible, or horny shell, the solution No. I. answers well; if by hard, calcareous plates, the solution No. II. is preferable. They vary in size from microscopic minuteness to upwards of a yard in length. The larger and middle-sized specimens should be kept by themselves, or sewed up in a bag if placed with others in the same jar or bottle. Rare and beautiful kinds, with transparent glass-like shells, may be captured by the towing-net in tropical seas. The minuter kinds have been commonly neglected, especially those of fresh water: any such species observed darting about in the fresh water of foreign countries should be preserved in tubes, in spirit or solution No. I. The larger kinds of marine crustacea should be suffered to die in fresh water before immersion in the preserving liquor. The different kinds of king-crab (*Limulus*), usually found on sandy or muddy coasts, are particularly worthy of preservation, in spirits or solution, with the ova or young.

In preparing crustacea for drying, care is to be taken to preserve all their external parts as perfect and as expressive of the natural progressive action as possible. Crabs and lobsters should be cleaned out as soon as practicable—*i. e.*, the soft internal parts and the flesh should be removed; and they should be soaked in fresh water previous to drying. The claws when large require to be separated at each joint for the purpose, and then refixed, or a small piece may be neatly removed and afterwards replaced. When dried, the specimens should be wrapped in very soft paper and then packed in cotton, so as not to allow of their being displaced in the case nor to touch one another. It is desirable, with regard to brilliantly-coloured crabs, to wash them over, after they are dried, with a thin coat of the following varnish:—

VARNISH FOR CRABS, EGGS, &c. No. I.

Common gum	4 oz.
Gum tragacanth	½ oz.

Dissolve these in three pints of water, add to the solution 20 grains of corrosive sublimate, and 20 drops of oil of thyme, dissolved in 4 oz. of spirit of wine; mix it well, and let it stand for a few days to separate: the clearer part is to be used as varnish; the thicker part forms an excellent cement.

A very important subject of investigation is the developement of the crustacea from the earliest period at which they can be observed to the assumption of the mature or parent form. The eggs, usually of some bright colour, attached beneath the tail of the female crab, lobster, or shrimp, should be examined for this purpose: the embryo, if in course of developement, may be readily seen by opening the egg under a moderately magnifying power (see the note on Microscopes). Drawings of the different forms or stages of the embryo should be made, if possible, and the eggs and embryos preserved in spirit or solution in small glass tubes.

INSECTA.

Some specimens of all kinds of insects should be preserved for anatomical examination in spirit or the solution No. I. Many of the softer kinds of insects and spiders can only be profitably so preserved. Care must be taken that the softer kinds of insects are not put into the same bottle with the harder kinds. Gauze nets must be used for catching the *Lepidoptera* (butterflies and moths) on the wing, and a fine muslin net, like a landing-net, for the water insects. Many species may be taken by spreading a cloak, or placing an open umbrella reversed under trees or bushes, and shaking or beating the latter. Caterpillars should be carefully placed in a perforated box with the leaves of the plants on which they are found feeding: they will often undergo their metamorphosis in this captivity, and no *Lepidoptera* are more perfect than those thus *bred*, as it is termed, if carefully watched. The perfect insect should be accompanied, if possible, by its *larva* (caterpillar) and *pupa* (chrysalis or cocoon), together with a specimen of the plant on which it is found feeding. The latter should be kept in an herbarium set apart for the purpose, and should have a number corresponding with that of the insect. *Larvæ* and *pupæ* may be preserved in spirit or solution, as well as a specimen of every perfect insect that can be spared, with a view to anatomical investigation. It must be remembered that the *larvæ* will very soon lose their colours when so treated, and, in order to retain these, a specimen or two of the larger ones and of their pupæ may be opened, the viscera removed, and the inside, after it has been brushed with arseniate soap, stuffed with cotton. Boxes lined with cork are the best conveyances for dried butterflies, moths, and indeed for insects in general; or they may be pinned in the crown of the hat until they can be transferred to a place of safety. The more delicate insects, such as butterflies, moths, sphinxes, the different species of mantis, the locusts, dragonflies, &c., after being killed by pressure on the thorax, should be pinned down while in a relaxed state, with the wings and legs kept close to the body, to save space and prevent collision. The pin should be greased or oiled to prevent rust, and, if pointed at both ends, the specimen more readily admits of being turned. The pin should be made fast so as to allow of the motion of the box in all directions, and the fastening must be adjusted to the weight of the insect. The harder winged insects may be killed by immersion in hot water, and after having been dried on blotting-paper may be laid carefully in boxes upon cotton, so as not to interfere with or injure each other. A ready mode of preserving beetles (*Coleoptera*), when found in abundance on any foreign coast, is to put them, when dried, in a box, on the bottom of which a layer of fine dry sand has been strewed. When the layer is overspread with beetles they must be covered with another layer of sand, and the packer must proceed with layers of beetles and sand alternately, till the box, which should be water-tight, is quite full, when it should be screwed down and pitched at the seams. Mr. Darwin preserved all his dry specimens of insects, excepting the lepidoptera, between layers of rag in pill-boxes, placing at the bottom a bit of camphor, and they arrived in an excellent state.

Mollusca (*Cuttles, Squids, Snails (land and sea), Slugs (land and sea), Shell-fish, Cowries, Limpets, and Bivalves, as Mussels, Oysters, &c.*).

"A superficial towing-net, another so constructed as to be kept a fathom or two below the surface, and the deep-sea trawl, are the principal agents for capturing these animals. But when the tide is at the lowest, the collector should wade among the rocks and pools near the shore, and search under overhanging ledges of rock as far as his arms can reach. An iron rake, with long close-set teeth, will be a useful implement on such occasions. He should turn over all loose stones and growing seaweeds, taking care to protect his hands with gloves, and his feet with shoes* and stockings, against the sharp spines of *echini*, the back fins of weevers (sting-fishes), and the stings of *medusæ* (sea-nettles). In detaching chitons and *patellæ* (limpets), which are all to be sought for on rocky coasts, the surgeon's spatula† will prove a valuable assistant. Those who have paid particular attention to preserving chitons have found it necessary to suffer them to die under pressure between two boards. *Haliotides* (sea-ears) may be removed from the rocks to which they adhere by throwing a little warm water over them, and then giving them a sharp push with the foot sideways, when mere violence would be of no avail without injuring the shell. Rolled madrepores and loose fragments of rock should be turned over. *Cypræœ* (cowries) and other *testacea* are frequently harboured under them. Numbers of *mollusca*, *conchifera*, and *radiata* are generally to be found about coral reefs."—*Broderip*.

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* Leather soaks, becomes softened, and affords a very poor protection to the feet. A pair of wooden shoes, such as those used by dyers, might be kept expressly for wading about reefs.

† A case knife, *in experienced hands*, is even a better instrument: but great care must be taken not to wound the ligamentous border of the shell of the chitons, and not to injure the edges of the limpets.

Holes in the coral rocks should be narrowly searched for Cephalopods, which frequently lurk in them, and are often betrayed by the little heaps of shells about the entrance of their dens.

Among the floating mollusca likely to be met with in the tropical latitudes is the *Spirula*, a small cuttle-fish with a chambered cell covered by the skin at the end of the body. An entire specimen of this rare mollusk is a great desideratum; and if it should be captured alive, its movements should be watched in a vessel of sea water, with reference more especially to the power of rising and sinking at will, and the position of the shell during those actions. The chambered part of the shell should be opened under water, in order to determine whether it contains a gas; the nature of this gas should likewise, if possible, be ascertained. As a part of the shell of the *spirula* projects externally at the posterior part of the animal, this part should be laid open in the living *spirula*, in order to ascertain how far such mutilation would affect its power of rising or sinking in the water.

In the event of a living pearly nautilus (*Nautilus Pompilius*) being captured, the same observations and experiments should be made on that species, in which they would be attended with more precision and facility, as the species is much larger than the *spirula*, and its shell external.

The towing-net should be kept overboard at all practicable periods, and drawn up and examined at stated intervals, as some of the rarest marine animals have been taken by thus sweeping the surface of the sea; but unless the towing-net be carefully watched and manœuvred, it will become filled with every description of filth from the vessel.

A sketch or drawing of molluscous and radiate animals, of which the form and colour are liable to be altered by death, or when put in spirit, will aid materially in rendering the description of the species useful and intelligible.

Some of each species should be preserved in spirit or the solution No. II. If they have died with their soft parts protruded, they should be suspended so as to prevent distortion from pressure. If the shell be of the spiral form, the whorls should be perforated with a fine awl so as to allow the spirit or solution to enter; otherwise, as the main body of the animal fills up the whole mouth of the shell, the deeper-seated and softer parts would become putrid before the preserving liquor could get to them.

Where the animal has been detached from its shell, the soft parts and the shell should be marked with corresponding numbers. When the animal is furnished with an *operculum* (the little door which closes the mouth of many turbinated shells), it should be carefully preserved; and, if detached from the animal, should be so numbered as to prevent the possibility of its being attributed to the wrong species. Shells should never be cleaned, but should be preserved as they come from the sea, taking care only to fill the mouths of those which are turbinated with tow or cotton to prevent fracture. It may be sometimes requisite to put a live shell into hot water, and boil it a minute or two, in order to dislodge the animal, which may then be removed with a crooked pin.

The land shells are found in various situations, as in humid spots covered by herbage, rank grass, &c.; beneath the bark or within the hollows of old trees, crevices of rocks, walls, bones, &c.; about the drainage of houses, or in the dry season by digging near the roots of trees. Early in the morning, especially in rainy weather, is the best time for taking them. The fresh-water kinds may be sought for in quiet inlets, on the sides of lakes, rivers, and brooks. The greater number of univalves occur at or near the surface, under the leaves of aquatic plants and among decayed vegetables; while the bivalves and certain univalves keep at the bottom, and are often more or less imbedded in the sand or mud, from which they may be raked into a landing-net.

With regard to the marine bivalves, rocks, submarine clay-banks, piles, stones, and indurated sand, should be carefully inspected for *Pholades*, *Lithodomi*, and other boring species. If the collector should find any of these perforators in the ruins of an ancient temple, or in the remains of any ancient works of art, or any adhering shells (*serpulæ* for instance) attached to the surface of such works, the specimens become doubly interesting, especially in a geological point of view. In such cases, the situation should be accurately noted, as well as the distance of the perforations from the surface of the sea, either above or below.

By digging with a wide-pronged fork in sand-banks, at low water, many bivalves, such as *Solens*, *Cardia*, *Tellinæ*, &c., will be procured alive; and if the inhabitants of the coast be accustomed to diving, their services should be secured for deeper water. Care must be taken not to separate the ligament which binds the hinge. When the animal is dead the shell will gape, and the soft parts may then be removed without injury. Attempts to open bivalves, while the animals are alive, generally terminate in great injury to the shells.

Naticæ, *Terebræ*, and various other arenicolous mollusks, may be discovered by the curious and characteristic tracks which they leave visible upon the smooth surface of the sand at low water. Various *Echinoderms* may be detected in the same manner.

For deep-sea shells the dredge is indispensable. Dredging requires experience to judge of the length of rope to be used; if there be too much on a sandy bottom, the dredge will bury itself; if too little, it will not scrape properly; on rocky bottoms the rope must be kept as short as possible; in deep water the dredge can only be made to act effectually by placing a weight on the line, which, as a rule, may be about one-third of the weight of the dredge, and placed on the line at about two-thirds of the depth of the water; the object is to sink the rope, and counteract the tendency it has to float the dredge. The contents of the dredge are best examined by means of sieves, of which three should be used, one over the other—first, a riddle, next a wheat-sieve, and third an oat-sieve: these may be fastened together; the contents of the dredge being emptied into the riddle, and water being poured upon them, the mud, &c., will be washed off, and the contents separated, so as to be very easily examined. By this plan a hundred-fold more will be discovered than can be found by searching in mud or sand in the usual manner. Besides shells, numbers of crabs, star-fishes, sea-urchins, worms, corals, zoophytes, algæ, &c., are procured by the dredge.

VERTEBRATA.

Fishes.

All specimens, not too large to be preserved entire, should be immediately plunged into spirit, glycerine, or solution. In the case of cartilaginous or soft-spined fishes, the solution should be No. I. Fishes with hard spines should be preserved in the solution No. II. It will be found to be convenient to have a common receptacle for the fresh-caught specimens; and to transfer them, after soaking a day or two, into the vessel, with fresh spirit or solution, in which they are to be sent home. As the colours are more or less evanescent, it is desirable that they should be accurately noted before death.

With regard to large specimens of the shark or ray kind, John Hunter recommended that "the abdomen should be first opened, then the head taken off by dividing the fish below the heart across the upper part of the liver, by which means the mouths of the oviducts if it be a female, the heart, and head are all preserved together.

"The tail, if a thick one, as that of a shark, may be taken off a little below the anus, and the trunk alone preserved for examination. If the trunk be too large, it should be cut through above the pelvis, and the parts contained in the hinder portion, as the claspers of the male, should be preserved in spirit.

"If a female, separate the two oviducts through their whole length, where they run along the abdomen, on each side of the spine; but keep them attached to the cloaca and surrounding parts, and preserve the whole.

"If with young, or eggs, take the whole out in the same way, without opening the oviducts.

"The peculiarities of the fœtus in these animals should be attended to.

"If not of the ray or shark kind, take out such parts from the abdomen as are uncommon or singular.

"If the fish be of the roe kind (*i. e.* osseous and cyclostomous fishes), then cut transversely through the fish near the lower part of the roe, some way above the anus. This saves part of the roe, with the connexion between it and the anus, the principal parts concerned in generation.

"The tail may be cut off some inches below the anus.

"The stomach and intestines may be saved, if anything particular is observed in them. They should be examined for the presence of entozoa, which, if adherent to the coats of the intestine, should be preserved with the part to which they are attached.

"Eyes of fishes are proper objects of preservation.

"Separate and preserve the heads of such fishes as have anything singular about the teeth or gills, and are too large to be preserved entire."

Preserve the jaws and teeth, together with the backbone, or some of the vertebræ, of every shark or large ray which is not otherwise preserved, being careful to keep the teeth and vertebræ of each individual attached together. Such specimens would be of great service in the determination of fossil teeth and vertebræ. A section of the jaws and teeth, with part of the vertebral column, should be preserved in spirits or the solution No. II.

Amongst the more interesting fishes of the Southern Ocean is the Port Jackson shark (*Cestracion Phillippi*). Moderate-sized specimens of this species should be preserved entire; and the head, vertebræ, with the dorsal spines, viscera, and especially the impregnated oviduct, should be placed in spirit or solution. The Southern Chimæra (*Callorhynchus antarcticus*) merits also the especial attention of the naturalist.

Certain rivers of Africa (*e. g.* the Gambia) and of South America contain a peculiar eel-like fish, the *Lepidosiren*, with filaments for fins, which burrows and becomes torpid in the mud during the dry season. The male and female of this fish, and the ova and young in different grades of developement, preserved in spirit, glycerine, or the solution No. I., are wanted, in order to complete its anatomical and physiological history.

With regard to most fishes preserved in spirit or solution, it is desirable to inject some of the preserving liquor into the alimentary canal, and, if the fish be large, to make a small opening into the belly. The more delicate specimens should be sewed or wrapped in linen, in order to preserve the scales.

For dry specimens the larger kinds may be skinned, and the skin should be washed on the inner side with the arsenical soap, and then loosely filled with cotton, wool, or tow. With regard to the smaller or moderate-sized specimens, the Curator of the Dublin University Museum states: "An excellent mode of preserving fishes, easily accomplished, may be thus described: Lay the fish on a table, with the side which you wish to preserve upward; then with scissors cut it, so as to separate the fins, skin of one side, mouth and tail, from the body and viscera; spread the skin so obtained on a linen cloth, fold it over it, and subject it to some small pressure; remove the cloth, and take away any portions of flesh which may appear easily removeable; then fold it in a dry cloth and subject it again to pressure —a board and a few weights or stones will do if no other press be at hand; repeat the operation at intervals until the skin becomes quite dry, then wash it well at both sides with the varnish No. I. When dry, sew it on strong paper, and you will have as it were a coloured drawing of your fish. The great advantages of this plan are the ease with which it is done, and the small space specimens occupy when finished; a large collection does not require more room than so many dried plants."

REPTILES (*Crocodiles, Tortoises and Turtles, Lizards, Snakes, Toads, Frogs, Salamanders, and Newts.*)

All these animals are best preserved, particularly the smaller kinds, in spirit or solution No. II. Both preserving liquors require to be changed once at least, if not twice; a piece of linen being wrapped round each specimen preserves the scales; this is requisite at least for the smaller lizards and snakes. In skinning lizards the operator must be very careful not to break the tail. The larger snakes may require to be skinned, when care should be taken to preserve the head attached to the skin, and the skins with the heads attached should be put into spirits. In flaying serpents great care must be taken not to damage the scales; and the operator should be cautious, for his own sake, when employed about the head of the poisonous species: a scratch from a fang of a rattle-snake or of a *cobra di capello* soon after death may be fatal. The heads of both poisonous and innocuous species should be preserved for the examination of their teeth.

Tortoises and turtles may be prepared in a dry state, the breastplate being separated by a knife or saw from the back, and, when the viscera and fleshy parts have been removed, restored to its position. The skin of the head and neck must be turned inside out as far as the head, and the vertebræ and flesh of the neck should be detached from the head, which, after being freed from the flesh, the brain, and the tongue, may be preserved with the skin of the neck. In skinning the legs and the tail, the skin must be turned inside out, and the flesh having been removed from the bones, they are to be returned to their places by redrawing the skin over them, first winding a little cotton or tow round the bones to prevent the skin adhering to them when it dries.

When turtles, tortoises, crocodiles, or alligators, are too large to be preserved whole in liquor, some parts, as the head, the whole viscera stripped down from the neck to the vent, and the cloaca, should be put into spirit or solution.

The bones of such specimens are especially desirable: they may be separated and scraped clean: all those of the same individual should be packed in a bag or box with bran, paper-cuttings, hay, or dried seaweed. The bones of the smaller species need not be separated. After detaching as much of the flesh as is practicable, the entire skeleton may be suffered to dry in a naturally connected state, and then may be laid in a box on cotton, tow, or other soft material, and covered with the same.

The eggs, at different stages of developement, of crocodiles, turtles, and tortoises, and also of the larger snakes, should be preserved in spirit or solution, as also the young animals. As the colours of most reptiles are much altered by spirit, a coloured sketch should be made, when practicable, of them either during life or immediately after death.

The batrachia or amphibia should be obtained in the different stages of their metamorphoses. The different species of the burrowing snake-like genus called *Cæcilia* are especially desirable in the young state. The gravid oviducts of these and of the viviparous kinds of salamander should be preserved in spirit, glycerine, or the solution No. I., together with the young of the perennibranchiate amphibia of the United States, called menopoma, amphiuma, menobranchus, siren.

Birds.

All the rarer kinds, especially the smaller species, should be preserved in spirits or the solution No. II. for anatomical examination. Of such as are too large to be preserved entire, the gullet, stomach, or gizzard, liver, intestines, ovary, oviduct, or the male organs, should all be taken out as low as the anus, and, with the cloaca, should be preserved in spirit or the solution No. I. The tongue and trachea with the lower larynx should be preserved wet by themselves; and if more than two specimens of a rare bird are captured, the head of one should be preserved in strong spirit, a small portion of the cranium being removed to allow the spirit to get to the brain.

The most common as well as convenient mode of preserving birds for zoological purposes is by removing and preparing the dry skin, with the head and feet attached, and a few words on the mode of performing this operation may be found of use. First put some cotton or bits of blotting-paper into the mouth of the bird to absorb the blood that may be there, and then tie the bill close by passing a thread with a needle through the nostril, and round the lower mandible; next, after parting the breast-feathers, the incision for skinning should be made from the lower point of the sternum, or breast-bone, to the tail, care being taken not to cut into the body. Whilst removing the skin, thrust cotton-wool between it and the body, at the parts not being operated upon, to keep the feathers clean, and prevent them from coming in contact with the moist parts. Having detached the skin of those parts on each side, the legs are next to be pushed through and cut off at the joint that protrudes; and then follows the more difficult process of separating the vertebræ near the tail. Having detached, however, the legs, and leaving the flesh upon them for the present, the operator must continue to separate the skin from the hind part of the body as well as he can, and then very carefully cut through the vertebral column near the tail, without injuring the skin above it; that of the back is then detached with much ease, and a little practice is now necessary to keep back the feathers of the breast while the skin is drawn over the shoulders; the wings should then be separated at the shoulder-joint, and the skin pulled over the neck, and very gently and carefully over the head, taking especial caution not to enlarge the auditory orifices or those of the eyes. With the majority of birds the skin may be drawn back over and from the head without much difficulty; but there are some, as woodpeckers and ducks, in which the head is larger than the neck, and consequently could not be drawn through that part without stretching the skin; it is advisable to make an incision in the skin at one side of the head, and thus uncover the skull to remove the fleshy parts, not for-getting the tongue, eyes, and brain. In small birds a quill cut in a slanting manner will be found useful to scoop out the brain; a little wool may afterwards be wound round it to remove any moisture that may remain in the hollow parts of the skull. Whilst skinning the head, upon reaching the eye it will be necessary to cut the tough membrane that surrounds that part. The brain and flesh being thoroughly removed, and the skin anointed with the arsenical soap,* the limbs are easily drawn back, a little cotton or tow being previously wrapped round the thigh-bones, and care being taken that no feathers adhere to the interior of the skin of them and are drawn in with it, and then (after putting some cotton into the cavities of the orbits) the head must be pulled forth by means of the bill, an operation requiring much caution, so as not to tear the very tender skin of the sides of the neck; this is frequently a rather difficult matter with beginners, and may be much facilitated by partially crushing the skull, which is easily put back into shape when the skin is again over it; bits of

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* *Receipt for Arsenical Soap.*

Camphor	5 oz.
Arsenic in powder	2 lbs.
White soap	2 lbs.
Salts of tartar	12 oz.
Lime in powder	4 oz.

Cut the soap in thin small slices, as thin as possible; put them in a pot over a gentle fire, with very little water, taking care to stir it often with a wooden spoon: when it is well melted, put in the salts of tartar and powdered chalk. Take it off the fire, add the arsenic, and triturate the whole gently. Lastly, put in the camphor, which must first be reduced to powder in a mortar by the help of a little spirits of wine; mix the whole well together. This paste ought then to have the consistence of flour paste. Put it into china or glazed earthen pots, taking care to put a ticket on each.

When it is to be used, put the necessary quantity into a preserve-pot, dilute it with a little cold water until it has the consistence of cream; cover this pot with a lid of pasteboard, in the middle of which bore a hole for the handle of the brush.

The three first ingredients in the above receipt may be used, if the whole cannot be readily obtained.

cotton should also be freely used to prevent the feathers being anywhere soiled by adhering to the skinned body, as they are extremely apt to do, despite all care, unless some such precaution be resorted to. Having now returned the skull within the skin, a little art is necessary in arranging the feathers of the head properly, which is best done with a large needle; the eyelids should be neatly placed, and not stretched too large, the feathers covering the ears disposed as they originally were, and the orifice of the ears contracted to its proper form; the feathers before and over the eye should also be set naturally; and lastly, the skin of the crown and occiput should be loosened or lifted from the skull, and not be pulled too tightly backward. The arsenical soap is to be sparingly applied to the inside of the skin, and the legs and beak brushed with a solution of corrosive sublimate. As regards the rest, it is as well to tie together, but not too closely, the bones of the two wings, to put a little cotton around these and the bones of the legs, and, in stuffing the bird, to avoid stretching the skin by putting in too much cotton, especially to avoid puffing out the neck, in which it is enough to prevent the skin of its two sides from adhering together; and, lastly, to mind that the bird is restored to its original length and proportions, and that the feathers are laid down as smooth as possible. In large birds, more especially, it will be found useful to put a reed or thin bit of stick up the neck, around which the stuffing of the neck may be wound; for this will prevent the tender skin of the neck from bursting, when dry, upon the specimen not being handled with sufficient care: and, in large birds, it is also necessary to make an incision above the elbow-joint of the wings extending along their under surface, and to remove from thence the muscles of that part. In general it will be found more easy to skin birds, after one or two trials, to the complete satisfaction of the operator, than to put them nicely into shape afterwards, in the form they are to take on drying: and, upon being dried thoroughly, they are to be rolled up in paper and tied round with a string.

Birds should be skinned as soon as they are cold; they cannot be kept so long as quadrupeds, and as soon as decomposition begins the feathers are affected; and, if the operation of skinning be deferred till it take place, they will drop off. The os coccygis, or rump-bone, should be left with the skin, otherwise the tail-feathers will be liable to fall out.

The nest, eggs, and young should be procured if possible.

To preserve the eggs of birds with their nests, each nest should be put into a round box just large enough to contain it. After having made a small perforation at each end of the eggs, and expelled their contents, some cotton should be laid upon them to keep them from being moved about, and the whole covered with the lid.

Large eggs, as those of the ostrich and cassowary, at different periods of incubation, should be preserved in spirit.

To each bird attach a note—1. The colour of the eyes, bill, and legs, before they fade. 2. The season of the year when killed, and in what locality. 3. If known, state whether male or female.

The skins of the domestic breeds of poultry and pigeons should be obtained from all parts of the world. A good collection of the races of our domestic birds might prove of more value than new or rare species.

The skeletons of birds may be prepared in a short time for sending home by removing the viscera, cutting away all the soft parts, breaking down the brain with a probe or stick, and washing it out by the "foramen magnum," or hole for the exit of the spinal marrow, and drying the skeleton with its parts naturally connected, except the head, which may be packed in the thorax; and the whole, when dry, packed in bran or sawdust. Admit the bones of only one individual into each bag or box, taking care to label it with the same number as that attached to the skin. The viscera and any other soft part which appears curious should be preserved in spirit or the solution No. I.

MAMMALS (*Hairy Quadrupeds, Seals, Porpoises, Grampuses, Whales*).

The smaller kinds, as bats, shrews, mice, may be preserved entire, in spirit or the solution No. II., an opening being made in the skin of the belly to give the preserving liquor access to the viscera, and care being taken not to crowd too many specimens in the same vessel. In all cases, since the preserving liquor becomes diluted and deteriorated by the blood and other fluids of the recent specimen, such specimen should be removed after a few days, according to the temperature, into fresh spirit or solution.

The larger mammals must be skinned, taking care that the head and feet remain attached to the skin, according to the directions subsequently given. Such skins, if transmitted either in spirits or the arsenical solution No. II., usually arrive in excellent condition, and may be mounted as well as if recently taken off the animal, which is never the case with such as have been dried. If the circumstances under which the animal is taken will admit of preserving the skeleton, that ought to be done; for its importance is of great moment in a physiological point of view, not only as relating to the organization of the animal, but as a measure of comparison with other living species, and with those which are extinct and only found in a fossil state. The natural skeletons of the domestic quadrupeds from different parts of the world are highly desirable. If want of space or other circumstances forbid the preservation of the entire skeleton, the skull is the most valuable part to select, and it should be preserved whenever the opportunity occurs.

The mode of preparing the skull of a mammal for the museum is to place the head in a jar of water until the soft parts become detached by maceration and putrefaction; being then washed clean, care being taken to prevent the loss of the small ear-bones, tongue-bone, or loose teeth, it should be placed in fresh water, and the water frequently changed, until the skull becomes free from offensive smell: it should then be exposed to the sun and air, and will in a few days become white. But this process is not requisite for the mere preservation and transmission of skulls; if the brain be broken down and extracted by means of a small flattened stick through the "foramen magnum," and the soft parts cut away, it may be simply dried, with the lower jaw and hyoid bone attached, and packed in bran, sawdust, or dried seaweed.

When the entire head of a duplicate mammal is preserved in strong spirit, for the examination of the brain and organs of sense, a small portion of the cranium should be removed and the membranes of the brain carefully cut to give the alcohol access to that organ.

The œsophagus and stomach should be preserved in spirit or the solution No. I., with a portion of the duodenum; and the cæcum, if any, with a small portion of the ileum and colon. If the animal be not too large, it will be preferable to cut off from the mesentery the jejunum and ileum, which (after their length and circumference and the nature of their contents have been ascertained and noted) may be thrown away, and then to strip down from the spine the contents of the abdomen, beginning at the diaphragm, so as to have the liver, stomach, spleen, pancreas, colon, &c., all with their attachments, taken out together as low as the rectum, where it lies in the pelvis, and, after being cleansed and the contents examined, put into spirits or solution No. I.

The heart and lungs may be preserved together, or, if too large, the heart alone with the large blood-vessels.

The contents of the pelvis, viz. the bladder and rectum, with the internal parts of generation, both male and female; also the external parts, not separated from the internal, with a large portion of the surrounding skin, should be left attached in their natural state, and preserved in spirit or solution.

If the female parts are in a state of impregnation, the whole are to be taken out, as before described, without opening the uterus, unless for the purpose of admitting the spirit for the preservation of its contents, where of large size.

The young of very large animals, as whales, seals, the walrus, elephants, &c., and all fœtuses or abortions, should be preserved entire: but if a young cetaceous animal be too large, the tail may be cut off below the anus, and the body put into spirit; and if this should be too big for one cask, the head may be taken off and preserved in another.

Of a full-grown whale, or other large animal, the following parts should be preserved:—

The eyes, with the surrounding external skin, their muscles and fat, in an entire mass. The organs of hearing. The brain. Sections of the spinal chord. The supra-renal glands. The ganglions of the sympathetic nerve. The beginning of the aorta and pulmonary artery, for the valves.

The mammæ of the female, with part of the surrounding skin; also the ovaria and uterus. The fœtus, when found in the belly, to be taken out with the whole of the uterus, vagina, ovaria, &c.

The penis of the male to be taken off as far back as to include the anus with it.

In skinning quadrupeds the skull and leg bones should always be retained. The first incision should be made from the breast along the middle of the abdomen; the skin is then easily separated from the body by the finger, occasionally helped with the knife. Upon reaching the legs, they should be cut through, the fore-legs by the shoulder-bone, and the hind-legs by the base of the thigh-bone. The whole of the leg-bones are to be left in their places until the operation with the other part of the body is completed. In skinning the neck and head, the skin must be turned inside out, great care being taken, in separating the skin from the head, that the ears and eyelids be not cut. The skin being drawn off the head as far as the ears, the head should be separated from the neck, and then freed from every particle of flesh, such as the tongue, &c.; and the brain taken out by making an opening at the back of the skull. The next thing is to skin the legs and the tail. In these parts, as in the neck, the skin must be turned inside out; all the flesh then being removed from the bones, they are to be returned to their places by re-drawing the skin over them, first winding a little cotton or tow round the bones to prevent the skin adhering to them when it dries.

In animals of moderate or large size it will be necessary to skin the face upwards, commencing from the lips, in order that all the flesh may be removed from the bones of the face.

In most colonies native assistants may be soon taught this process, and nothing more is necessary beyond washing and then wiping the skin tolerably dry, if it is to be put into spirit or solution: but if intended to be sent home dry, then the interior surface, with the bones, must be anointed with arsenical soap, and likewise the nostrils, ears, and lips, internally; and the hair or fur ought to be wetted with a weak solution of corrosive sublimate. The skin should then be stuffed with tow or cotton, but *not tightly* so as to stretch it.

In warm climates of course it is necessary to skin the animal immediately after death, and it is very desirable that the skin be kept in the shade. Large quadruped skins should be immersed in a strong solution of alum, in which they may remain three or four days, and when taken out of the alum-water they should be washed on the inner side with arsenical soap,* especially about the skull and bones of the feet; a painting-brush may be used for this purpose, and the soap should be mixed with water until it has the consistence of cream: a very small quantity of soap is sufficient; it should not be used too freely. When it is inconvenient to use alum-water, the powdered alum may be used in a dry state, and should be well rubbed over the whole of the inner side of the skin.

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* See p. 388.

Packing.—Great care should be taken in packing skins that they be thoroughly dry. They should be packed in wooden boxes, and some pieces of camphor must be placed with them in order to prevent the attacks of moths. Tobacco is often used, but does not always answer the intended purpose. When soldered up in tin boxes, specimens often become mouldy, and are sometimes perfectly destroyed by the damp.

Labelling specimens.—The labels or numbers should never be placed on the paper or wrapper in which a specimen is enclosed: in this case they often become accidentally transferred, especially in the examination which the specimens undergo at the custom-house, &c. Small parchment labels, with the locality of the specimens, should be securely tied to the legs or some other convenient part; a number corresponding with the collector's note-book should also be attached; this number may be stamped on a small piece of sheet-lead or trebly thick tin-foil; when specimens are preserved in spirit the latter must be used, since the former will corrode and injure the specimens. A set of steel dies, from 0 to 9, with a small punch, should be got, when the numbers may at any time be stamped in a line, with a hole punched in front of each, and then cut off with a pair of scissors as wanted.

Notes.—The collector should note down the colour of the eyes or *irides*, and the form of the pupil, and the colours of those parts (the naked parts, *e. g.*) which are likely to be altered in drying; also the form of the head and muzzle, and the habitual position of the ears and tail. The exact locality in which the several specimens were procured is of great importance in the determination of the laws of geographical distribution of mammalia: and not only the country, but the nature of the country, its elevation and geological character, as nearly as can be ascertained. Also the degree of commonness of the animal and any of its known habits, and the native name.

Neither shape nor colour can be preserved in the dried skins of whales, porpoises, &c., nor can they be ascertained from skins alone, without the aid of drawings taken from the specimens in a fresh state. Skins of the cetaceans (whale and porpoise tribe), and of seals, are, nevertheless, great desiderata for public museums, and, with the addition of sketches and notes of the recent animal, are especially recommended to the attention of the naturalist voyager. The skulls or skeletons of all the species of the southern cetaceans and seals should be preserved, the sex being noted.

As the greater portion of the smaller mammals are of nocturnal habits, they can seldom be procured without the aid of traps, which must be baited, some with flesh or a dead bird, some with cheese, bread, fruits, &c.: small pits, widest at the bottom, and baited, often serve to entrap small quadrupeds.

Necessary materials for determining Species.—In almost all cases the zoologist is desirous of examining more than one specimen—in fact, of having before him at least a specimen of the male, female, and young animal, and also one or two skulls, before he can give a satisfactory description of a new species, that is, such a description that the animal may be with tolerable certainty identified through its means. When one specimen only can be procured, the skull should not be injured; a little extra time is well spent in removing the brain through the occipital opening, the back part of the skull being of importance. When the species are small, and several specimens can be procured, one at least should always be preserved in spirit or solution.

THE HUMAN RACE.

The chief points to which the attention of the philosophic and zoological voyager should be directed towards the advancement of this most important branch of Natural History are included in the following queries:—

What is the average or general stature and weight of the individuals, and the extreme cases?

Is there any prevailing disproportion in the size of the head? of the upper or lower extremities?

What is the prevailing complexion, and the colour of the eyes?

What is the colour of the hair, and its character, as fine or coarse, straight, curled, or woolly?

Is the head round or elongated in either direction? Is the face broad, oval, lozenge-shaped, or of any other marked form? (A profile and also a front view should be given.)

Does infanticide occur, and to what causes is it to be referred?

What is the practice as to dressing and cradling children? Are there any circumstances connected with it tending to modify the form of particular parts, *e. g.* the head or the feet?

Are the children easily reared?

At what age does puberty take place?

Are births of more than one child common? What is the proportion of sexes at birth and among adults?

To what age do the females continue to bear children? And for what period are they in the habit of suckling them?

What is the menstrual period, and what the time of utero-gestation?

What are the ceremonies and practices connected with marriage?

Is polygamy practised, and to what extent?

Is divorce tolerated, or frequent?

How are widows treated?

What is the prevailing food of the people? Describe their modes of cooking.

What number of meals do they make, and what is their capacity for abstinence, and for temporary or sustained exertion?

Describe the kind and materials of dress; and any practice of tattooing or otherwise modifying the person for the sake of ornament or distinction.

Do the people appear to be long or short lived? State the ascertained cases of extreme old age.

What is the general treatment of the sick, and the superstition, if any, connected with it?

What are the prevailing forms of disease?

Do Entozoa prevail, and of what kind?

How are the dead disposed of?

What is the received idea respecting a future state?

What are the kinds of habitations in use amongst the people?

Have they any monuments; and of what kind, and for what object?

What are the domestic animals, if any? Whence derived, and whether degenerated or modified?

Note down any illustrative particulars of the government, policy, religion, superstitions, or sciences of the people; their mode of noting or dividing time; their mode of carrying on war, and favourite weapons.

In these researches collect and preserve the skeletons, both human and of other animals that may be buried or preserved with man: with any works of art or implements.

Besides the *skeletons*, or, at least, the *skulls* of aborigines of foreign countries, plaster casts of the head, the hands, and the feet should be taken; and wherever the opportunity may occur, the *brain* should be preserved in strong alcohol.

Important aids to the advancement of zoology may be rendered by the transport of living animals, and more especially their transmission to the Menagerie of the Zoological Society of London, for which purpose the following remarks have been contributed by a former Vice-President of the Society, William John Broderip, Esq., F.R.S. :—

"In the endeavour to bring a captured animal home alive, it will be well to remember that the younger quadrupeds and birds are—provided they are of an age to be separated from the mother with safety—the greater will be the chance of success in bringing them home in a thriving state. There is hardly any young vertebrated animal which judicious kindness will not render familiar. The captive should be kept clean, and should be fed sparingly; that is, it should have only sufficient to sustain it in health; all trash should be kept out of its reach, and it should not be subjected to the capricious kindness or ill-treatment of strangers.

"Herbivorous quadrupeds, and hard-billed or seed-eating birds, are obviously most easily accommodated during a voyage; but carnivorous animals and insectivorous birds may be transported without much difficulty by paying attention to their food and habits.

"It would be far from impracticable for ingenuity to devise a mode of introducing even humming-birds alive into this country. A strict attention to temperature, and the aid of an artificial florist, might effect this. If it be found that the birds will not feed out of little troughs, quills, or tubes of coloured paper,* the flowers which are observed to be their favourites might be imitated, and liquefied honey, or even sugar and water, might be placed in a little reservoir in the site of the nectarium. To take these brilliant creatures alive is not difficult, if the following method be adopted. Some plant (the aloe for instance), the flowers of which are particularly attractive to the humming-birds, being selected, all the bunches of blossom, save one or two, should be broken off in the evening, after the birds have retired. These bunches should be enclosed in light bamboo trap-cages, with large open falling doors kept up by strings, to be held by a person in concealment. A little before the usual time of the appearance of the humming-birds, the bird-catcher must be in his hiding-place with the door-strings in his hand, and when he finds his prize busily employed about the enclosed flower, he must drop the door and secure his prey. Mr. Bullock tried this plan with great success; and, while on this subject, it may not be irrelevant (as connected with their diet) to state that he saw these birds frequently take insects out of the spider's webs, where they lay entangled, and swallow them; and that Mr. George Loddiges has observed the remains of insects in the crops of some of those species which he has opened.

"Reptiles are so tolerant of hunger, and are gifted with such tenacity of life, that they bear a voyage extremely well. Turtles (*Chelones*) and alligators are brought over without difficulty, and tortoises and terrapenes (*Testudines*) may be imported almost without trouble. It is not uncommon for those who touch at the Gallapagos, where great land tortoises abound, to put them into dry casks, one over the other, without any provision; and, after many weeks, they are found not only alive but in excellent condition for the table, where they are said to exceed turtle in delicacy of flavour.

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* Captain Lyon, in his 'Journal of a Residence, &c., in the Republic of Mexico,' p. 212, states that he kept a humming-bird for nearly a month on sugar and water, slightly impregnated with saffron. It greedily sucked this mixture from a small quill; and the Captain adds, that he is sure that, with constant attention, these little creatures might be kept for a long time.

"Guanas, chamæleons, together with others of the lizard tribe, and all serpents, bear abstinence from food for a long time, and are brought from their native countries with little trouble.

"Insects may be taken in the caterpillar stage when about to enter the chrysalis state, and in this manner may attain their imago, or perfect developement, either on the voyage or after their arrival, by attention to their habits and to the temperature of their natural locality.

"The terrestrial or pulmoniferous *Mollusca* (land-shells) may be brought over alive with ease. When they show a disposition to hybernate, by sticking firmly to the side of the box or vessel wherein they may be, and at the same time throwing out the thick parchment-like secretion which serves many of the species instead of a true operculum, they should not be disturbed, but must be kept dry, and, if possible, excluded from the air. Many species have been thus accidentally imported. *Bulinus undatus* was brought sticking to timber from the West India islands into Liverpool, and is now naturalized in the woods near that town. The author possessed living specimens of *Bulinus rosaceus*, which had been brought to England by Captain King and Lieutenant Graves, R.N., from Chiloe, and were in full vigour, though the animals had been packed up in cotton, with the collection of shells, one for eighteen months and another for two years. He now possesses one in good health, brought home by Mr. Cuming, which had been packed up for a longer time. *Testacellus* and other species had been imported previously.

"By strict attention to changing the sea-water, which very soon becomes unfit for respiration when put into a vessel, marine *conchifera*, *mollusca*, and *crustacea* might be brought home alive, and an opportunity given of studying their organization much more satisfactorily than can be done by a mere *post-mortem* examination.

"The land-crab of the West Indies has been brought over with success. A pair of them were exhibited, in full vigour, for a few weeks at the end of summer, in one of the enclosures open to the air, at the Zoological Gardens."

Specimens of Fossils should always be accompanied with part of the rock in which they occur, whether stone, clay, or sand, &c.

All fossils, without exception, may be brought home, in as large number as may be obtained and conveniently packed.

When fossils occur in sand or gravel, note their condition as to freshness or decomposition; whether they resemble those of the adjacent coast or seas; the mode of their occurrence; whether regularly interstratified with clay or stone; in patches, or continuously, on the sides of hills or of cliffs, and at what altitudes above the sea.

State whether the fossils found in any given situation are all marine, terrestrial, or fluviatile; mixed, or in distinct groups; and, if mixed, in what proportions.

Observe whether there be any intermixture of fresh-water and marine shells in bodies of water near the shore, or in lakes at a distance from it.

Inquire whether bones of mammalia occur among them.

Note the brackishness of the water; whether it communicates or not with the sea. State any differences of the animals from those of purely fresh, and of salt water.

Observe carefully the *position* of fossils in the beds which afford them. If corals, whether vertical or inclined? If shells, are they disposed in layers parallel to the strata?

Notice whether testacea are carried up to cliffs by birds: the quantity of shells thus accumulated, and their state of preservation.

Notice the relative number of shells of the same species on the shores.

Seek for and preserve all traces of *fossil bones*.

Be careful to ascertain that they are imbedded in the alluvium, not loose or intermixed with the *recent* detritus.

If any bones should be *dredged* up, note the place of their occurrence, its latitude and longitude, its distance from any great rivers, and whether within currents.

Bones in caves.—Examine the materials forming the bottom of caves for bones.

Bone-breccia.—Search for this in crevices.

Observe all indications of coal, and collect specimens; note any traces of vegetable impressions in the rocks, and preserve them carefully.

Seek with the microscope for infusorial animals, both in a fossil and recent state.

On the Use of the Microscope on board Ship.

The facility in examining the smaller invertebrate animals, either alive or dead, depends much more on the form of the microscope used than would be at first expected. The observer should possess two microscopes, a simple and a compound one; so that an object may be transferred from a low to a high power without delay. It frequently happens that a small transparent animal remains in one position for only a very short time; and in the interval required for the screwing and unscrewing of lenses, a favourable opportunity may be lost not to return again. The chief requisite of a simple microscope for this purpose is strength, firmness, and especially a large stage; the instruments generally sold in this country are much too small and weak. The stage ought to be firmly soldered to the upright column, and have no movement; besides the strength thus gained, the stage is always at exactly the same height, which aids practice in the delicate movements of the hand. The stage should consist merely of a roughened brass-plate with a circular aperture and diaphragm; and, as it is a great matter to place objects under the microscope with as little disturbance as possible, the object-holders should not drop or fit into anything. The best receptacles for the objects are glass cells (such as are used for the preservation of specimens) of various sizes and depths, cemented to oblong pieces of plate-glass of uniform size. These are not readily broken, and are easily and accurately slid by the fingers (after a little practice) to any required position. A disc of blackened wood, with a piece of cork inlaid in the centre, is useful for opaque and dry objects: there should also be a disc of metal of the same size, with a hole and rim in the centre to receive plates of glass, both flat and concave, in diameter one inch and a half, for dissecting minute objects; a plate of glass of three inches diameter lets in too much light, and is otherwise inconvenient. Close under the stage there should be a blackened diaphragm, to slip easily in and out, in order to shut off the light completely; in this diaphragm there may be a small orifice with a slide, to let in a pencil of light for small objects. The whole microscope should be screwed into a solid block of oak, and not into the lid of the box as is usual. The microscope is most conveniently fixed by making its base to *drop* into a cavity in a broad thin block of wood, which should be loaded with lead and covered with green baize or felt below. If the wooden block be broad enough, the instrument will not fetch away in the heaviest rolling.

The mirror should be capable of movement in every direction, and of sliding up and down the column; on one side there must be a large concave mirror, and on the other a *small* flat one; these mirrors ought to be fitted water tight in caps, made to screw off and on; and two or three spare mirrors ought undoubtedly to be taken on a long voyage, as salt water spilt on the mirror easily deadens the quicksilver. A small cap is very convenient to cover the mirror when not in use, and often saves it from being wet. The vertical shaft by which the lenses are moved up and down should be triangular (as these work much better than those of a cylindrical form), and there should be on both sides *large* milled heads; with such there is no occasion for fine movements of adjustment, which always tend to weaken the instrument. The horizontal shaft should be capable of revolving, and should be moved to and fro by two milled heads (for the right and left hands), but the left milled head must be quite small, to allow of the cheek and eye approaching close to the lenses of high power. The horizontal shaft must come down to the stage.

The most useful lenses are doublets of 1 inch and 6-10ths of an inch (measured from the lower glass of the doublet) in focal distance; a simple lens of 4 or 5-10ths of an inch is a very valuable power; and, lastly, Coddington lenses (of the kind sold by Adie of Edinburgh), of 1-10th, 1-15th, and 1-20th focal distances, have been found most useful by two of the most eminent naturalists in England. With a little practice it is not difficult to dissect under the 1-10th lens, and some succeed under the 1-20th. A person not having a compound microscope might procure a 1-30th of an inch Coddington lens. All the lenses (except the largest doublet) should be made to drop, *not screw*, into the same ring; the large doublet may slip off and on the opposite end of the horizontal shaft. The best saucers have a flat glass bottom, with the upright metal sides (silvered within); there should be at least four of them, being in depth (inside measure) 3-10ths, 5-10ths, 7-10ths, and a whole inch. Circular discs of fine-textured cork, of the size of the saucers, either permanently loaded with lead or kept down by little leaden weights, serve for fixing objects to be dissected by direct instead of transmitted light. For this end short fine pins and lace-needles should be procured; wherever it is possible, the animal ought to be fixed to the cork under water. Common sewing-needles answer every purpose both for fixing and dissecting. If for the former end, they should be fine and their eye-ends should be covered with a little head of sealing-wax. If for the latter purpose, they may be ground on a hone, and bent to any shape. As to handles, glass tubes are too frangible for a ship, and too smooth and too small to give good hold to the fingers. The ends of used-up pencils, the thicker the better, do admirably well. Of the smaller plates of glass of an inch and a half in diameter, some should be flat and some slightly concave; the latter are very useful—saucers of this small diameter are inconvenient.

The simplest and most useful instruments for minute dissection are the triangular glove needles, which with a little cotton-wool and sealing-wax can be easily fixed into pieces of large-bored thermometer tubes; a stock of tubes and needles should be taken on a voyage. With these needles (by keeping the object only just immersed in a drop of water, which can be regulated by the suction of blotting-paper) wonderfully minute objects can be dissected; needles bent at their tips are convenient for some purposes. Arm supports are useful in minute dissections; two blocks of wood with inclined surfaces, coming up a little below the level of the stage, and resting partly on the stand of the microscope, can be made by a common carpenter. As it is often rather dark in the cabins of ships, a large bull's-eye glass on a stand (such as are sold with most compound microscopes) would be most useful to condense the light from a lamp on an opaque object, or to increase it when transmitted. Besides the needles, fine pointed forceps, pointed scissors, and eye scalpels are requisite. A French instrument, called a microtome, is very useful, as it may be made to perform the part of knife, scissors, and forceps; and thus render any change of position of the hand unnecessary. Finely pointed scissors, with one leg long and thick, to be held like a pen, and the other quite short, to be pressed by the fore-finger, and kept open by a spring, are preferred by some, but are awkward to use, and very liable to become spoilt in consequence of capillary attraction of the sea-water into the hinge. They must be very carefully cleaned and oiled after use. A live-box to act as a compressor, or, still better, a proper compressor closed by a screw, and both made to drop into the rim of the stage, are valuable aids for making out the structure of transparent animals or organs. The observer should be provided with three slips of glass, or, still better, with three circular plates, made to drop into the stage of his microscope, and graduated into tenths, hundredths, and thousandths of an inch, to serve as micrometers, on which to place and measure any object he is examining. Some watch-glasses are very useful as temporary receptacles for small sea animals. Minute parts after dissection can be preserved for years in very *weak* spirits of wine, by covering them, when placed on slips of glass, by small portions of very thin glass (both sold for this purpose), and cementing the edges with gold-size.*

With many delicate animals, particularly acalephæ, which would be injured by the pressure of their own weight, and for which, therefore, the compressor is inapplicable, but which must, nevertheless, be covered with glass in order to their examination under a high power, a good plan is, to take a glass cell, just large enough to contain the animal, fill it quite full of water, then transfer the animal with a glass tube, or by other means, to the cell, and cover the top over the cell with a piece of thin glass, so as to exclude all air-bubbles. The animal will adhere to, and become slightly flattened against, the thin glass, and may be examined with great facility.

The observer cannot be too careful in ascertaining that both good workmanship and good material have been employed upon the mechanical details of his instrument.

Defects, such as a worn-out rack, or a spoilt screw of an object-glass, are not to be replaced on board ship, or in any country he is likely to visit.

When time and opportunity concur for the anatomical examination of an animal, the following notes or heads of observation will guide the dissector to the facts which it is most desirable to determine and note down.

No. Date 18 .

Notes of Dissections performed at

Animal's Name

Sex Age Weight

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* A microscope such as here described, and most of the apparatus, can be seen at Messrs. Smith and Beck's, opticians, of Colman Street, London.

Length of body, from extremity of jaws to root of tail
——— of head   of tail
Situation of testes
——— of preputial orifice
——— of vaginal orifice
——— of anus
Situation and number of mammæ
Abdominal muscles
——— ring
Stomach
- simple
  - length   greatest circumference
  - *Observations*
- complex
  - number of sacs   relative size
  - *Obs.*

Omentum
Mesentery
Intestines
- length   greatest circumference
- —— of small   —— of small
- —— of cæcum   —— of cæcum
- —— of large   —— of large
- *Observations*

Anus   glands
Cloaca.
Liver
- situation
- number of lobes
- weight
- *Observations*

Gall-bladder, size   situation
——— structure
Bile, enters intestine
Pancreas
- form
- situation
- its secretion, enters intestine

Spleen
- situation
- form
- weight

Lungs
- situation
- length   breadth, right   left
- weight
- number of lobes, right   left
- structure, air-cells, &c.

Branchiæ
Heart
- situation
- weight
- length   breadth
- shape and structure

Venæ cavæ
Aorta, primary branches
Trachea, number of rings structure
Larynx
Pharynx
Epiglottis
Thyroid glands
Salivary glands
Tongue, length papillæ
Nostrils
Eyelids
Eye
Pupil, form
Lacrymal gland
Ear
Brain, weight form, &c.
Spinal cord, length
Supra-renal glands

Kidneys
- situation
- form length breadth
- weight of both
- papillæ, number and form

Ureters terminate

Urinary bladder
- situation
- size
- shape

Testes
- size
- structure

Vasa deferentia terminate

Vesiculæ seminales
- size
- structure
- terminate

Prostate
- size
- structure
- terminate

Cowper's glands
- size
- structure
- terminate

Penis length muscle
Urethra

Ovaries
- situation
- size
- shape
- *Observations*

Uterus
- length of cornua
- ——— of Fallopian tubes
- ——— of body
- position

Vagina

Oviduct	length form termination

Peculiarities of muscles
———— of air-sacs
———— of glandular organs
Morbid appearances
  Calculi
  Entozoa
  Epizoa

General Directions to be observed during a Voyage.[*]

The towing-nets should be kept overboard whenever it is practicable, and the dredge should be used perseveringly in soundings.

The anchor should be inspected as soon as it arrives at the surface, especially if the holding ground be mud. The finest shells have been lifted on the flukes of anchors. The cable should also undergo an examination.

Let the arming of the lead be narrowly observed, and let the men have orders to preserve anything that may be sticking to the arming, the lead itself, or the lead-line.

Floating masses of seaweed, especially *sargasso*, should be carefully searched; and if one of those tangled natural rafts, which are often carried adrift from great rivers, should be seen, it should be examined minutely, and the animals, plants, and seeds which it may be transporting to colonize some newly-formed island, should be preserved, if possible, or, at all events, accurately noted.

Whenever a new marine species, or one whose habits are unknown, is obtained, it should be placed in sea-water, and, if practicable, a drawing should be made of it while yet alive, with a note stating whether it is gregarious or solitary —phosphorescent or not—and giving the locality, the temperature, the state of the weather, the depth of water, and the time, where and when it was captured. The sea-water in which living marine animals are confined should be often changed; for it speedily becomes unfit for life.

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[*] From 'Hints for Collecting,' &c., by Wm. John Broderip, Esq., F.R.S.

If a turtle (*Chelone*) be taken, the shell should be examined for parasitic barnacles (*Chelonobia*) and other adhesions. The specimens ought not to be scraped off, but the plate of shell to which they are affixed should be taken out, and the whole should be preserved together. Whales should be searched for *Coronulæ*, *Tubicinellæ*, &c.: they should be left, as they are found, in the skin and blubber of the animal, and the piece with its contents should be plunged in spirits.

The stomach and intestines of those fishes and birds which are killed during the voyage should be inspected before they are thrown away, not only for the purpose of noting their food, but for the chance of finding undigested shells, &c., and in search of *Entozoa*. The feathers of birds should be examined with a view to ascertain whether any parasitic insects, any ova of fish or *testacea*, or any seeds of plants, adhere to their plumage. Their crops will often be found stored with fruits and seeds, which they disseminate in their flight.

Particular attention should be paid to the appearance of birds or insects, as well as to the direction whence they seem to come, with a view to the elucidation of their migration.

By placing in the sea clean planks of wood, the rate of growth of *Teredo navalis*, and of the *Cirripedia*, together with the ravages made by the former in a given time, may be ascertained. *Serpulæ* will probably be found on the board also, and perhaps other shells. This experiment should be repeated whenever an opportunity occurs, and in different localities and climates. Some of the planks should be painted, others covered with pitch, others studded closely with copper and other nails, and some should be in their natural state.

When on shore in search of terrestrial *mollusca* (land-shells), the collector must not be content with a close examination of the trunks, leaves, and stems of trees and other plants, but must turn up all decayed vegetable substances, especially in moist places, and there dig into the earth, more particularly about the roots of trees, and under overshadowing bushes and shrubs. Stones must be lifted, herbaceous plants must be pulled up and their roots inspected, and, if the boat's crew be at hand, fallen trunks of trees should be turned over with handspikes. All ova must be preserved; and the height above the level of the sea at which the specimens were taken, and the plants on which any of them were feeding, must be noted. In the latter case the plants should be preserved in an herbarium, and numbered as directed under the head of insects.

No boggy places, especially where streamlets ooze out, should be passed without examining the rushes and other plants there growing, for fresh-water *testacea.* At the proper season their ova may be found adhering to living and dead stems of plants, leaves, &c.

No bird, insect, shell, or any other zoological specimen, should be neglected because it does not strike the eye as beautiful, or because it is small and appears to be insignificant. Such objects are often the most interesting.

When a box or barrel of specimens is once securely packed, it should never be opened till it arrives at the place of its destination. If it is wished to have a few duplicates at hand, for the purpose of exchange with other collectors who may be met during the voyage, some specimens should be set aside for that purpose. All observations should be noted down while the impression is warm; and, if possible, with the subjects actually before the observer.

When an object is seen afloat, attracting notice by its magnitude or other peculiarity, and is not captured, its nearest approach to the ship, its mode, course, and rate of progression, and the parts actually recognisable, should be noted, at the time, with the utmost accuracy. If practicable a boat should be put off for close observation. If the observer has not the zoological knowledge, or the opportunity for exact inspection, requisite for determining the species from the phenomena, he should abstain from giving the object any special name. Supposing it to be an animal, a shot fired, if it do not hit, may so alarm the creature as to cause some sudden movement which may reveal more of its true nature.

ARTICLE XV.

FOURTH DIVISION, SECTION 5.

BOTANY.

BY SIR WILLIAM HOOKER, K.H., D.C.L., F.R.S., &c. &c.,

DIRECTOR OF THE ROYAL GARDENS OF KEW:

Assisted by DANIEL HANBURY, Esq., F.L.S.

BOTANY is a science which requires to be studied at home as well as in the field. For this reason it is highly desirable that persons visiting a foreign land should not only obtain information on the spot respecting its plants and their uses and properties, but that they should transmit to this country ample collections of *well-preserved specimens*. These may consist of *living plants* or of *pressed and dried botanical specimens* and of *fruits* and *seeds*, also of various vegetable products. By the last term we mean such objects as *medicinal substances* (barks, roots, gums, resins, and the like), *dye-stuffs*, useful *fibres*, interesting *woods*, *oil-seeds*, with the oil prepared from them, *farinaceous substances*,—in fine, whatever of vegetable origin deserves attention on account of its utility to man.

Let us therefore offer in the first place a few plain instructions for collecting and transporting plants in foreign lands.

Living Plants for Cultivation.

Plants for cultivation in our European gardens may be introduced either as *seeds*, *bulbs*, *tubers*, *cuttings*, or *rooted plants*.

Seeds, *bulbs*, and *tubers* are easily collected, and as easily transmitted to Europe from very distant countries. The first, *seeds*, require to be gathered quite ripe; to be wrapped, a quantity of each, in dry and not absorbent paper, done up in a parcel, and kept if possible, while on board ship, in an airy part of the cabin. *Bulbs* and *tubers* should be taken up when the foliage has withered; and, if well dried, they may be packed in the same way as seeds.

Cuttings.—Generally speaking, it is vain to attempt sending *cuttings of plants* to a distance, for they soon perish; but this is not the case with the greater number of *succulent* plants—those with thick and firm fleshy stems and leaves. Such are many of the *Cactus tribe* in South America; the various succulents of South Africa, as *Aloes*, *Euphorbias*, *Stapelias*, *Mesembryanthemums* or *Fig-Marygolds*, the *Houseleek* kind, &c. Many of the *Bromelia*, or Pine-apple tribe, and the *Agaves* or *American Aloes*, will survive a long time as cuttings. The cuttings should be taken off, if possible, where there is a contraction or articulation of the stem, or at the setting on of a branch. The wound ought to be dried by exposure to the sun; and the cuttings may be packed in a box, with paper wrapped about them, or any dry elastic substance to keep them steady.

Rooted Plants.—Some few of these, namely, such as are of a succulent nature, small plants of *Cactus*, *Aloë*, *Bromelia*, *Tillandsia*, and *Zamia*, &c., and (which are now highly valued in European stoves) the various *Epiphytes* or *Air-plants*, those numerous *Orchideous plants* and others of the *Arum tribe*, which clothe the trunks and branches of trees in tropical countries:—all these will bear a long voyage if removed with their roots and stowed in a box, like the cuttings above described, the larger kinds surrounded with dry straw. But plants, in general, when taken up with their roots (and young ones should be preferred), can only be securely transported, placed in earth, in Ward's plant-cases, now generally known and most deservedly esteemed: these cases are glazed at the top or roof, so as to be in fact small portable greenhouses. The plants should be established in the cases some days before sending them off, secured by splines, so as to confine the roots in the soil in the event of the box being overturned, and moderately watered. The lid is then fastened with putty and screws; and the case, being placed on the deck of a vessel so as to be exposed to the light, which is an indispensable requisite, will require no watering nor any attention (unless the glass happens to be broken) during the entire voyage.

On Preserving Plants for the Herbarium.

This is by no means the difficult process which many have imagined. The object is to prepare the specimens in such a manner that their moisture may be *quickly absorbed.* the colours, so far as possible, preserved, and such a degree of pressure imparted that they may not shrivel in drying.

For these purposes provide a quantity of paper of moderate folio size and rather absorbent quality—brown or stout grey paper answers the purpose exceedingly well. An excellent kind, when not to be used in a hot and moist country, is *Bentall's botanical paper*, 16 inches by 10, which costs (folded) 15*s.* a ream; or of larger size, namely, 20 inches by 12, 21*s.* per ream. It is sold by Newman, No. 9, Devonshire Street, Bishopsgate Street, London. In a hot and moist region, brown paper may be employed with advantage. Two boards are requisite, of the same size as the paper, or a trifle larger, one for the top, the other for the bottom, of the mass of papers. Some pieces of millboard placed between the specimens, if these are numerous or particularly thick and woody, are very useful. For pressure nothing is better than a heavy weight on the topmost board, or, while travelling, three leathern straps and buckles, two to bind the boards transversely, and one longitudinally. Thus provided, gather your specimens, if the plant be small, root and stem; if large, take off portions of the branches, a foot or rather more in length, always selecting those which are slender and in flower, or in a more or less advanced state of fruit. Long slender plants, as *grasses*, *sedges*, and many *ferns*, may be doubled once or twice. Place them, as quickly after being gathered as you can, side by side, but never one upon the other, on the same sheet of paper, taking care that one part of the bundle be not materially thicker than the other; and lay over the specimens one, two, three, or more sheets of paper, according to the thickness of your paper and of your plants; and so on, layer above layer of paper and specimens, and subject the whole to pressure. In a day or two, according to the more or less succulent nature of the plants and the heat and dryness of the climate, remove them into fresh papers, twice or oftener, till the moisture be absorbed, and dry the spare papers in the sun or by a fire for future use.

If the specimens cannot be laid down as soon as gathered, they should be deposited in a tin box, which indeed is essential to the botanist when travelling; there they will remain uninjured for a day and night, supposing the box to be well filled and securely closed to prevent evaporation. Some very succulent plants, and others with fine but rigid leaves—the heath and pine tribe, for example—require to be plunged for an instant into boiling water ere they are pressed. In this case the superabundant moisture must be absorbed by a cloth or by blotting-paper.

When sufficiently dry the specimens should be put into dry papers, one sheet or folio between each; except they be unusually woody (which is the case with oaks and pines), and then more paper must be employed, care being used to distribute the specimens pretty equally over the sheets, and thus a great many may be safely stowed in a small compass. A slip of paper should be placed with each specimen, stating its name, if known, and the date and place of collection. Specimens so arranged are now ready for transport, either packed in boxes or covered with oil-cloth.

Mosses and cryptogamous plants may be generally dried in the common way: those which grow in tufts should be separated by the hand to form neat specimens. Seaweeds require a slight washing in fresh water, and common blotting-paper is the best for removing the moisture from this tribe of plants.

It is almost needless to add that *all plants*, whether living or dried, ought to be transmitted to Europe with the least possible delay; the latter, especially in hot or moist climates, are often soon destroyed by the depredations of insects.

Museum of Vegetable Products.—The above short instructions refer solely to the collecting and despatching *living plants*, and to *dried specimens;* in other words, the means of furnishing our gardens and the herbarium. We have now to mention another important branch of the science, hitherto much neglected, but towards which travellers will do well to contribute—we mean the Museum of Vegetable Products, or it may be called the "Museum of Economic Botany." Its design is to bring together in one spot and to exhibit those interesting vegetable products from all parts of the world which cannot be shown in the living plants of a garden or the preserved plants of an herbarium. The public may now see growing in our Botanic Gardens the rare *Lace-tree* of Jamaica, the yet rarer *Ivory Palm-nut* of the Magdalena, and the *Cow-tree* from the Caraccas. The interest of these is greatly enhanced, when, in the same establishment, the curious and beautiful lace of the first, the fruit and ivory-like seeds of the second, and the cream-like substance of the third, used as nourishment by the Indians, can be inspected.

Among the objects, therefore, which are to be collected for the museum are—

1. *Fruits and Seeds*, especially those which are of large size and possess any peculiarity of form and structure entitling them to notice, such as *Pine-cones*, the various fruits of *Palms*, &c. &c. Many of them are naturally dry, and require little care (except to be freed from moisture) previous to packing. Those which are about to burst open into valves, or to separate by their scales (as the *cones* of *Pines* and *Araucarias*), should be bound round with a little

packthread. The soft and fleshy kinds can only be preserved in wide-mouthed bottles or jars, or casks (according to size), in alcohol, or in diluted pyroligneous acid.

2. *Flowers* which are very large or particularly fleshy, and therefore unsuited to the *Hortus Siccus*, should be preserved in alcohol or pyroligneous acid. Among those which would be much prized are, for instance, portions of the flowering branches of *Palms*, &c., and the larger kinds of *Orchidaceæ*.

3. *Entire Plants* or parts of them. Many have a very fleshy nature, and must be preserved whole in alcohol, or portions of the stem and branches, according to their size, with flower and fruit; such are the rare kinds of *Stapelia*, *Orchidaceæ*, *Misseltoe*, *Rafflesia*, *Mesembryanthemum*, *Cactus*, *Aphyteia*, *Balanophora*, *soft Parasites*, and others of a similar sort.

4. *Trunks of Trees*, portions and sections, particularly when they exhibit any remarkable structure, as Palms, and many other monocotyledonous plants, *Tree-ferns*, *Zamia*, *Cycas*, and *parasitical* stems, when these latter display their union with the tree whereon they grow.

5. *Woods.*—Specimens of the kinds employed in commerce, for veneering, cabinet-work, or other useful purposes; or such as recommend themselves by their beauty, hardness, or any other valuable quality. Specimens of wood should be truncheons, 5 or 6 inches long, and of a foot or a foot and a half diameter. Generally speaking, it is advisable that a small branch dried and pressed, with leaves, flowers (and fruit, if convenient), should accompany the specimen of wood, in proof of the *precise* tree or plant from which the latter is derived, and, if not the scientific, the native name should be written.

6. *Dye-stuffs* of various kinds.

7. *Medicinal Substances*, *Gums* and *Resins* employed in the arts, *Oil-seeds* and *Oils*, &c.—These are of considerable importance, and merit the attention of travellers in every country. With respect to many well-known medicinal substances, it is remarkable that we are still in uncertainty

as to the plants which yield them. As much interest attaches to this branch of knowledge, a special list of inquiries, in a detailed and precise form (see p. 421), has been drawn up, which it is hoped may lead to the collection of information and specimens that will elucidate the obscurity still attaching to many substances of this class in very common use.

8. *General products of Vegetables.*—It is extremely difficult, perhaps impossible, to enumerate all of these which a museum ought to contain; but the enlightened traveller will form a tolerably correct judgment. Such as are useful to mankind cannot fail to be interesting. It were of course idle to exhibit every well-known object of this description, *tea*, *sugar*, *coffee*, *cocoa*, *chocolate*, *paper*, *clothing*, &c.; but there are states even of these familiar substances which would prove both useful and instructive. The *cane yielding sugar*, for instance, is advantageously exhibited. *Paper*, again, is made from an infinite variety of vegetable substances; and the different sorts are well worth collecting, from that afforded by the *Papyrus of the ancients* (which gives the name), to that manufactured from the inner bark of an East Indian *Daphne*, or from the leaves of a *Palm* in India, or from *straw* in North America. Of all such, the several stages of preparation should be collected, not only as objects of curiosity, but because they exemplify the progress of art and science.

A question will naturally suggest itself to the traveller, not previously versed in the vegetable productions of different parts of the globe, "In what regions can I most effectually serve the cause of botany?" The answer is ready: In almost every portion of our world the inquiring mind will find objects for study; though assuredly the less the country has been tracked by Europeans and men of science, the more fertile it may be expected to prove in novelty. But even where the coast has been visited and tolerably accurately investigated, the interior, especially if mountainous (and the loftier the mountains the more varied the vegetation), will afford an ample field for research. Even with regard to many frequented spots it has been truly observed that few persons visit them "with their eyes open." Thus, while some travellers boldly assert that the vicinity of Aden is utterly destitute of vegetation, others have detected plants of very peculiar structure, and admirably adapted to such a locality; and one estimable naturalist, Pakenham Edgeworth, Esq., has actually published a *Florula* entitled 'Half an Hour's Botanizing Excursion at Aden,' giving an account of forty species gathered during that brief time, eleven of which are considered new to science!

One has only to glance at a map of the world, and it will be instantly seen that much of it is unknown alike to the botanist and the geographer. The extensive interior of South America, particularly towards the sources of the great rivers, the deserts and mountain-chains of Africa, the table-lands of Thibet, with the northern declivities of the Himalayan Mountains, the Chinese dominions, Japan, and many of the numerous islands of the Malayan Archipelago, are still a *terra incognita* to the naturalist. But it is not to such little traversed realms alone that we need look for new and interesting vegetable productions, particularly of the more useful kinds, those of many of our own colonies being still very imperfectly known.

With regard to botanical books, it is difficult to recommend any of a general character suitable for the traveller. Many of the best collections of plants have been made without books; and, unfortunately, there is no *complete or Universal Flora* yet published. De Candolle's '*Prodromus Systematis Naturalis Regni Vegetabilis*' is the best, and it is advancing towards a termination; and Walpers' '*Repertorium Botanices Systematicæ*' is a valuable supplement to it. Don's '*Dictionary of Gardening and Botany*' is useful, so far as it goes: it is in 4 vols., 4to., published at 14*l*. 8*s*., but now offered by many booksellers at 1*l*. 8*s*.! Dr. Lindley's various introductory works on Botany ought to be in the hand of every student, and, above all, his '*Vegetable Kingdom*.' Loudon's '*Encyclopædia of Plants*,' with its numerous woodcuts, is an excellent travelling companion. And for any particular country it is desirable to ascertain the books that may happen to describe the vegetation of it. They are too numerous to allow of a list being here given.

Upon pharmacological subjects, Lindley's '*Flora Medica*' (London, 1838, 8vo.), Pereira's '*Elements of Materia Medica and Therapeutics*' (2 vols. 8vo.), and Guibourt's '*Histoire Naturelle des Drogues Simples*' (Paris, 1849-51, 4 vols., 8vo.), will be found valuable modern works of reference.

As a means of directing the attention of travellers and those resident in foreign countries to some of the subjects that have been alluded to, we have drawn up the following list of

BOTANICAL AND PHARMACOLOGICAL ENQUIRIES AND DESIDERATA.

AFRICA—WEST COAST, ALSO EAST COAST, INCLUDING THE RED SEA AND ARABIA.

Copal.—Information is much desired respecting the varieties of this substance which are found in commerce, and which are exported from the West Coast of Africa. Some copal is believed to be dug from the ground, but one variety at least is collected from the tree. This is the Sierra Leone copal, and is produced by *Guibourtia copallifera*, Bennett, *Kobo* of the natives: specimens of this tree, including the ripe pods, are requested; it grows at Goderich and in other localities near Sierra Leone.

Grains of Paradise.—Although *Amomum Melegueta*, Roscoe, the plant which yields this drug, is now well known, there are some other interesting species nearly allied, with which botanists are very imperfectly acquainted. It is, therefore, desirable to procure specimens of such plants from various parts of the West Coast of Africa. These specimens should comprise the flowers and fruits, as well as the foliage. As the flowers are very delicate, it is necessary to preserve some specimens in spirit of wine or in dilute acetic acid. Some specimens of the fruits should also be preserved in the same manner. As the species often grow intermixed, and as flowers and fruits are produced at different seasons, special care is requisite to avoid confusion.

Korarima Cardamom is the name under which the late Dr. Pereira has described an Abyssinian cardamom, having the shape and size of a small fig, which is exported from Mussowah, a port at the southern end of the Red Sea. This drug, which has long been known in medicine, is perforated at the smaller end, and, when strung upon a cord, is commonly used by the Arabs and Abyssinians as beads for their *mesbehas* or rosaries. It is said to be brought to the market of Baso, in Southern Abyssinia, from Tumhé, a country situated in about 9° N. lat. and 35° E. long.

The plant, for which the name *Amomum Korarima* has been proposed, is entirely unknown.

Olibanum.—The Olibanum found in European commerce is believed to be produced partly on the African coast, near Cape Gardafui, and partly on the southern coast of Arabia, whence it is shipped to Bombay.

Olibanum is also produced in India by certain species of *Boswellia*, called *Salai* or *Saleh*, one of which is *B. glabra*, Roxb., another *B. thurifera*, Colebr. It is extremely doubtful if the Olibanum, afforded in India by these trees, finds its way to Europe, but information on this point is desired.

African Olibanum is yielded by a tree called *Plösslea floribunda*, Endl. (*Boswellia*, Royle); but as the drug varies considerably in appearance, it is highly probable that it is obtained from more than one species. The variety called *Lubân Mattee*, from its being shipped at Bunder Mattee, is, for instance, a very different drug from ordinary olibanum.

A resident at Aden may be able to gather some information upon this subject as well as upon the next.

Myrrh.—This celebrated drug is collected in great quantities by the Somali tribes on the African coast, near the southern extremity of the Red Sea, whence it is brought to Aden for shipment to Bombay.

A variety of myrrh, which is probably yielded by another species, is also produced (according to Vaughan) in a district lying forty miles to the east of Aden, to which place it is brought for sale.

A third variety, distinguished by the Arabs as *Bissa Bôl*, is also collected by the Somali tribes and sent by way of Aden to India.

It is a point of much interest to determine with accuracy the plants which afford these several sorts of myrrh, and for this end it is earnestly requested that those who have any opportunity for investigating the subject will not neglect to do so.

ASIA MINOR, PERSIA, CENTRAL ASIA.

Gum Tragacanth is produced in Asia Minor by several species of *Astragalus*, which it is desirable further to identify. Travellers and others who have the opportunity should preserve specimens of any species *seen* to yield the gum, as well as specimens of the gum itself; noting at the same time whether the latter was obtained from incision in the stem, or whether exuded spontaneously. Fine gum tragacanth is produced at Caissar (or Kaisarieh) and Yalavatz, in Asia Minor, at which places the practice of making longitudinal incisions in the stem of the shrub is adopted; the gum is also collected at Isbarta, Bourda, Angora, &c.

Gum tragacanth is frequently adulterated with another gum, which has been called *False Tragacanth*, *Hog Gum*, *Bassora Gum*, or *Gum Kutera*. At Smyrna it appears to be known as *Caraman Gum*. What is its origin? One of its properties is to swell up into an opaque mass, upon being placed in water, in which, however, it does not dissolve.

Storax.—None of the storax found in commerce in modern times is derived from *Styrax officinale*, L.; yet it is certain that this tree is capable, under favourable circumstances, of yielding a highly fragrant resin which was once much valued.

Authentic specimens of this resin, which is the original and legitimate *Storax*, are much desired. It was formerly produced in the south of Asia Minor, where the tree is still found in great abundance.

Salep.—Obtain specimens of the different plants which yield salep in Asia Minor, Persia and Cashmere, and especially of those that afford the best kinds.

What is the plant which affords the drug called *Badshah Saleb*, or Royal Salep? Where is it produced, and for what purpose is it valued? It has been exported to England from Bombay.

Sumbul Root.—Nothing definite is known respecting the botanical origin of this remarkable root, which is said to come into Europe by way of Russia. It is probably produced somewhere in Central Asia.

Assafœtida.—Although the ordinary assafœtida of commerce is doubtless the produce of *Narthex Assafœtida*, Falc., there are some varieties of the drug which, it is reasonable to conclude, are derived from other species. One of those sent from India to the Great Exhibition of 1851 was a brown pelluoid gum-resin containing pieces of the stalk of the plant, and differing considerably from ordinary assafœtida.

Another variety, which has long been known, has been called *Stony Assafœtida*, from its containing about 50 per cent. of gypsum, an addition which, in the case of so cheap a drug, it is difficult to understand.

Assafœtida is produced in Persia, and reaches Europe by way of Bombay.

Sagapenum, a gum-resin resembling assafœtida, but not acquiring a pink colour upon exposure to the air, and of not so strong an alliaceous odour. As it is occasionally shipped from Bombay, it is presumed that it is produced in Persia. Though it has been used in medicine for ages, its botanical origin is not ascertained; from analogy, however, we may infer that it is the produce of some large plant of the nat. order *Umbelliferæ*. Compared with assafœtida and galbanum, sagapenum is a rare and costly drug.

Galbanum.—The remarks we have made upon sagapenum apply to a great extent to the gum-resin known as *Galbanum*. Galbanum is, however, a far more abundant substance than sagapenum. It occurs in trade in two varieties, which are so distinct as to lead to the inference that they are yielded by distinct plants.

Galbanum is said to be imported into Russia in large quantities by way of Astrachan, but that which reaches England comes principally from Bombay.

Opopanax, another fœtid gum-resin, the produce, according to most authorities, of *Opopanax Chironium*, Koch, a large umbelliferous plant, native of the south of Europe, and of Asia Minor. There is no modern account of the collection of this drug, nor is its place of production ascertained.

Rhubarb.—Determine the true source of the various sorts of *medicinal* rhubarb, especially of the Chinese rhubarb sold at Kiachta to the Russians, and of that exported from Canton. Strange to say, we are still in the dark respecting the real origin of this most valuable drug! In this and all such cases the drug should be procured by one who is an eye-witness to it being gathered, and specimens of the foliage, flowers, and fruit, carefully dried for the herbarium on the spot, should accompany it.

INDIA, SIAM, INDIAN ARCHIPELAGO, CHINA, &c.

Catechu.—Observe the processes by which the various kinds of *Catechu*, *Cutch*, *Terra Japonica*, and *Gambir* are obtained; and if from trees, whether from others besides *Acacia Catechu*, *Areca Catechu*, and *Uncaria Gambir*. We wish to identify the trees with the respective extracts.

Grass Oils.—The grasses used in India for affording the fragrant essential oils, known as *Lemon-grass Oil* or *Essence of Verbena*, *Ginger-grass Oil*, *Citronelle*, &c., require investigation. What, for instance, is the source of the essential oil imported from Ceylon as *Oil of Lemon-grass?* It is considered quite distinct from *Citronelle*, which is also a production of the island.

Benzoin or *Gum Benjamin.*—Obtain complete specimens of the tree which affords this drug in Siam.

Cardamoms.—The so-called *Wild* or *Bastard Cardamom* of Siam is produced by *Amomum xanthioides*, Wallich, a plant of which *complete* and *well-preserved* specimens are requested in order that it may be described and figured.

The seeds *per se* have been imported into England, while the empty capsules are found in the drug-shops of China. Are the latter exported from Siam to China?

What is the origin of the cardamom called by the Chinese *Yang-chun-sha*, the *Hairy China Cardamom* of pharmacologists? It is said to be produced in the province of Kwang-tung, and it may be a native of Cochin China.

Nothing is known of the origin of the scitamineous fruit to which the name *Large Round China Cardamom* has been given, and which is known to the Chinese as *Tsaou-kow.* The same remark applies to the *Bitter-seeded Cardamom*, *Yih-che-tsze*, and *Ovoid China Cardamom*, *Tsaou-kwo* or *Quâ-leu*; it is probable that all of them are productions of the south of China, or of Cochin China.

Cassia Bark.—Specimens are much desired of the tree which affords this bark in Java, on the Malabar coast, in the south of China, and in Cochin China. Botanical specimens should in all instances include good samples of the bark, young and old, obtained from the same tree.

Cassia Buds.—These are the immature fruits of a *Cinnamomum*, native of Cochin China, specimens of which are requested.

An inferior kind of Cassia Buds, known as *Lovengoopoo*, is found at Madras. What is the species that affords it?

Aromatic Barks of other *Laurineæ*, as *Culitlawang*, *Massoy*, *Sintoc*, are objects of commerce in the Indian Archipelago, and are but imperfectly known in Europe. The traveller should embrace the opportunity, when it occurs, of seeing the bark collected, and of obtaining authentic specimens of it, and of the tree yielding it.

Massoy Bark is produced on the west coast of New Guinea.

Galangal Root.—Endeavour to procure the plant affording this drug, which is imported from the south of China.

Elemi.—This resin is abundantly produced in the forests of the Philippines, where it often assists in giving a cheerful blaze to the fire of the traveller. It is also exported from Manilla as a drug. The tree that affords it, is probably a *Canarium*, but it is desirable to have complete specimens in order to ascertain the species with exactness.

Elemi is also produced in Mexico, where it is known as *Copal;* it occurs in commerce in scraped pieces, which are semi-cylindrical, yellowish, semi-opaque, and having the usual strong and fragrant odour of Elemi. This drug is the produce of *Elaphrium elemiferum*, Royle, a tree occurring near Oaxaca, of which specimens are requested in order that it may be further examined and described.

There are other resins, of whose origin little is known, which have been imported from Mexico, Brazil, and other parts of tropical America as *Elemi.*

CENTRAL AND SOUTH AMERICA.

Sarsaparilla.—The species of *Smilax*, the roots of which constitute the various sorts of sarsaparilla found in commerce, are very imperfectly known. Good botanical specimens, comprising flowers, fruits, and leaves, and accompanied by the stem and roots, should be carefully preserved and transmitted to England for determination.

The so-called *Jamaica Sarsaparilla* grows near the Chiriqui Lagoon, in the state of Costa Rica, and a species very similar, if not identical with it, at Bajorque, on the Rio Magdalena, New Granada. Other sorts of sarsaparilla are produced in Mexico, Guatemala, Honduras, Brazil, &c. That of Guatemala grows in the department of Sacatepeques in that state.

Rhatany Root.—A variety of this drug has been exported of late years from Savanilla, in New Granada. Obtain specimens of the plant from which it is derived.

Malambo Bark, a highly aromatic bark, produced in New Granada. Of its origin nothing certain is known.

Balsam of Copaiva is imported from several parts of Brazil: it varies somewhat in properties, and is the produce of several species of the genus *Copaifera*. It is desirable to obtain the balsam of each species, with a specimen in flower and leaf, and, if possible, in fruit, of the tree affording it, and the name of the district where the tree grows, and its native appellation there.

Lignaloe.—The name of a remarkably aromatic wood sent to the Paris Exhibition of 1855, from the department of Vera Cruz, in Mexico. By what tree is it afforded?

Lignum nephriticum.—This rare wood was sent to the Paris Exhibition of 1855 from Mexico. To what tree is it to be referred?

Cinchona Bark, or *Peruvian Bark.*—This valuable drug, the only source of quinine, is derived from various species of *Cinchona* growing along the whole chain of the Andes, from New Granada to Bolivia. Of these trees it may be said that good, pressed, botanical specimens of *any* species are interesting and desirable. Such specimens ought to include the flowers and fruits, and in every case to be accompanied by several pieces of the bark, young and old, stripped from the *very* tree from which the botanical specimens were gathered: all being most carefully and clearly labelled upon the spot with every particular worthy of note.

A point of considerable interest, still to be determined, is the *proportion* of alkaloids contained in the *young* and *old* bark. For this determination two or three pounds of each sort of bark are requisite; and for a perfectly fair experiment they ought to be collected from the same individual tree.

The attention of Englishmen residing in the countries indicated is especially requested to this by no means unimportant question.

Balsam of Peru.—The drug known under this designation is produced, not in Peru, but in Central America, in a district lying between Acajutla and Port Libertad, in the western part of the state of San Salvador, known as the *Balsam Coast.* The tree which affords it, may also be found at Ispanguasate (where it has been planted), and near Chiquimulilla, and on the coast of Suchultepeques. Of this tree, which is the *Myrospermum Pereiræ* of Royle, good flowering specimens are much desired, as are also fresh seeds, in order that the plant may be raised in our hothouses. The seeds should be transmitted by post, as their vitality is not long retained.

The balsam which is called *Balsamo negro*, is brought for sale to Sonsonate, previously to shipment at Acajutla.

Although the plant above-mentioned is undoubtedly that which affords the balsam of Peru of commerce, yet there is reason to think that a balsam of similar character was formerly extracted from other species. Monardes (1565) states that balsam of Peru is *lighter* than water, but the balsam of modern times is *heavier*. Inquire into this. Is not balsam prepared at Chongon, near Guayaquil? Is any produced in Mexico? We have received the seeds of a *Myrospermum* from that country.

Balsam of Tolu.—Myroxylon Toluifera, H. B. K., the tree which affords this substance, is very imperfectly known. It grows in New Granada, in the neighbourhood of Turbaco, and especially in the high savannas near Tolu, Corozol, and the town of Tacasuan. It is also found at the mouth of the river Sinu, near El Zapote, and here and there on the banks of the Rio Magdalena, in the environs of Garapatas and Mompox.

Is it not possible to obtain at least the seeds, not to mention a supply of good botanical specimens, of this famous tree, and some account of the extraction of and trade in the balsam it affords?

THE END.

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